

The Effectiveness of Infrastructure and Expertise on the Acquisition of Stickhandling  
and Puck Control Skills in Competitive Hockey Players

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## ABSTRACT

The purpose of the study was to compare the effectiveness of two sport-specific training methodologies using a novel stickhandling and puck control (SPC) training device; physical practice (PP), and physical practice and observational learning (PP+OL), on skill acquisition and retention of SPC skills in competitive hockey players. Male (N=40), atom-aged (2005/2006 birth years), hockey players were recruited to participate and assigned to one of three groups; PP (n=16), PP+OL (n=15) and control (n=9). All groups completed one 50-minute familiarization session and two assessment sessions [pre-training ( $A_{pre}$ ) and post-training ( $A_{post}$ )] consisting of off- and on-ice assessments. The PP group received eight, 50-minute on-ice SPC training sessions. The PP+OL group received the same on-ice training, plus an additional 10-minute observational learning session before each on-ice session. Only PP and PP+OL completed a retention assessment ( $A_{ret}$ ) following a two-week period of no training. The off-ice assessment consisted of height (cm), weight (kg) and a modified Aggiss and Walsh (1986) coordination assessment (# of successful repetitions). The on-ice assessment consisted of two forward skating drills measuring execution time (s) and five SPC drills, measuring interval time (s), execution time (s) and execution competency. Execution competency was assessed on a 12-point scale for each device within each SPC drill by an expert rater. Multiple two-way mixed analysis of variance (ANOVA) revealed no significant interactions between groups in execution time or competency on any of the five SPC drills, combined overall total time (COTT) or total competency (COTC). Significant main effects of training were revealed across the three assessments for execution time on

3/5 SPC drills and COTT, and execution competency on 1/5 SPC drills. A Bonferroni post hoc revealed execution time for  $A_{\text{post}}$  and  $A_{\text{ret}}$  were significantly faster than  $A_{\text{pre}}$  for 2/5 SPC drills and COTT, and execution time for  $A_{\text{post}}$  was significantly faster than  $A_{\text{pre}}$  for 1/5 SPC drills ( $p \leq .05$ ). The control group revealed no significant differences between  $A_{\text{pre}}$  and  $A_{\text{post}}$  for execution time or competency. In summary, eight, 50-minute on-ice SPC training sessions elicited an improvement in execution time while maintaining competency, however, the combination of PP+OL did not reveal further training benefits.

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## TABLE OF CONTENTS

ABSTRACT .....	ii
ACKNOWLEDGMENTS .....	iv
LIST OF TABLES .....	viii
LIST OF FIGURES.....	ix
CHAPTER 1: INTRODUCTION .....	1
CHAPTER 2: LITERATURE REVIEW .....	4
2.1 Skill Learning.....	4
2.1.1 Learning Theories .....	4
2.1.2 Motor Memory Processes.....	6
2.1.3 Challenge Point Framework.....	7
2.1.4 Motor Skill Acquisition.....	9
2.2 Observational Learning.....	10
2.2.1 Social Learning/Cognitive Theory .....	11
2.2.2 Observational Learning Variables .....	13
2.2.3 Types of Skills .....	17
2.2.4 The Combination of Physical Practice .....	19
2.3 Hockey Demands .....	19
2.4 Purpose .....	22
2.5 Null and Alternative Hypotheses.....	22

2.6 Significance of Study.....	23
CHAPTER 3: METHODOLOGY .....	25
3.1 Participants.....	25
3.2 Study Design .....	25
3.3 Familiarization Protocol .....	26
3.4 Assessment Protocol .....	26
3.5 Training Intervention.....	29
3.5.1 Physical Practice Group (PP) .....	29
3.5.2 Physical Practice and Observational Learning Group (PP+OL) .....	30
3.5.3 Control Group .....	31
3.6 Adherence.....	31
3.7 Statistical Procedures .....	32
CHAPTER 4: RESULTS.....	34
4.1 Subject Descriptives .....	34
4.2 Off-ice Assessment .....	34
4.3 On-ice Assessments .....	36
4.3.1 Skating Assessments .....	36
4.3.2 SPC Assessments .....	37
CHAPTER 5: DISCUSSION .....	44
REFERENCES.....	56

TABLES .....	67
FIGURES.....	78
APPENDIX A – Glossary Terms.....	86
APPENDIX B– Letter of Invitation .....	88
APPENDIX C – Informed Consent .....	92
APPENDIX D– Hockey Experience Questionnaire.....	94
APPENDIX E – Assessments.....	95
APPENDIX F - Criteria Checklist for SPC Drills.....	98
APPENDIX G – On-ice Training Drills.....	99
APPENDIX H - DNF Criteria .....	101

## LIST OF TABLES

Table 1: Summary of Cognitivist Learning Theories.....	67
Table 2: Training Group Protocols.....	68
Table 3: Summarized Player Descriptives .....	69
Table 4: Summarized Player Questionnaire Responses .....	70
Table 5: Coordination Assessment Scores (Mean $\pm$ SD) .....	71
Table 6: Execution Time (s) of Skating without Puck (Mean $\pm$ SD).....	72
Table 7: Execution Time (s) of Skating with Puck (Mean $\pm$ SD) .....	73
Table 8: Within Group Paired Samples T-Test for Execution Time of All Drills(t, df and p) .....	74
Table 9: Within Group Paired Samples T-Test for Execution Competency of All Drills (t, df and p).....	75
Table 10: Execution Time (s) of SPC Drills (Mean $\pm$ SD) .....	76
Table 11: Execution Competency (rating) of SPC Drills (Mean $\pm$ SD) .....	77



## LIST OF FIGURES

Figure 1. Study Timeline .....	78
Figure 2. Hockey Rink Diagram.....	79
Figure 3. Combined Overall Total Time (COTT) by Group .....	80
Figure 4. Combined Overall Total Competency (COTC) by Group.....	81
Figure 5. Overall Time of Simple Drills by Group.....	82
Figure 6. Overall Time of Complex Drills by Group .....	83
Figure 7. Overall Competency of Simple Drills by Group .....	84
Figure 8. Overall Competency of Complex Drills by Group .....	85

## CHAPTER 1: INTRODUCTION

Advances in training practices and methodologies have seen an increase in sport-specific training devices created and marketed to facilitate technical skill development. Skating treadmills and shooting simulators are examples of such infrastructure that when packaged with training expertise or methodologies are proposed to be effective (Lockwood & Jackson, 2010). The link between infrastructure and expertise is the theoretical framework upon which the current study is proposed.

In a broader context beyond sport-specific skills, the acquisition of motor skills is primarily achieved through two learning methodologies: (i) physical practice or learning that occurs as a result of physically performing the skill through repetitions and, (ii) observational learning or learning that occurs as a result of seeing, retaining and imitating the behaviors of others (Bandura, 1977; 1986). Physical practice is considered the primary stimulus for learning a motor skill. It provides the learner with an opportunity to experience and update the movement repetition through sensory consequences of the action being learned (Andrieux & Proteau, 2013; Trempe, Sabourin, Rohbanfard, & Proteau, 2011). The learning acquired through observing the actions of others, resulting in the development of either a cognitive or motor skill is known as observational learning (Bandura, 1969).

The combined effect of learning methodologies, for example, physical practice and observational learning has resulted in significantly greater increases in motor skill acquisition compared to either learning methodology in isolation,

despite limited research in this area (Andrieux & Proteau, 2013; Deakin & Proteau, 2000; Laguna, 2008; Shea, Wright, Wulf, & Whitacre, 2000).

As proposed by Guadagnoli and Lee (2004), the challenge point framework (CPF) relates learning to the amount of information available through the relationship and interactions of motor task difficulty and performer's skill level. Providing the learner with a balance between skill level and task difficulty creates the optimal challenge point to maximize learning by actively involving problem-solving skills during training (Guadagnoli & Lee, 2004). Using the CPF theoretical model to guide motor skill practices can be an effective way to implement progressions during training.

In the sport of ice hockey, shooting, specifically scoring is the skill associated with successful performance, however, stickhandling and puck control (SPC) contributes significantly to the players' ability to maneuver in tight spaces, maintain possession and optimize scoring opportunities. Sport-specific motor skills like SPC skills are typically introduced, acquired and perfected through multiple repetition-type practices. The literature exploring traditional SPC training methods has been limited to practitioner or coach focused articles on how to teach skills as opposed to investigating the effectiveness of methodologies.

The current study's training methodology was theoretically driven by combining infrastructure (novel training device) and expertise (combination of learning methodologies). The training packaged a novel, sport-specific training device, designed to both stimulate and challenge SPC skill development and a physical practice methodology, designed to simulate the SPC demands of the games

including training in small areas, with traffic while emphasizing upper body coordination, change of directions, edge control, read and react skills, quick feet and creativity. In addition to the physical practice methodology, an observational learning methodology was selected to determine if the combination of methodologies would supplement SPC skill development through an 8-session training intervention. Research combining the two learning methodologies have suggested potential enhancement of motor skill acquisition and retention compared to isolated methodologies.

Therefore, the purpose of the study is to compare the effectiveness of two sport-specific training methodologies using a novel SPC training device; physical practice (PP) and physical practice and observational learning (PP+OL), on skill acquisition and retention of SPC skills in competitive hockey players. Effectiveness was defined as a significant improvement in execution time and/or execution competency.

## CHAPTER 2: LITERATURE REVIEW

**2.1 Skill Learning****2.1.1 Learning Theories**

In relation to skill acquisition/development, learning is defined by Schmidt (1975) as a change in performance as a result of practice or experience. Prominent theories of learning include Fitts and Posner's (1967) Three-Stage Theory, Gentile's (1972) Model of Learning, Adams' (1971) Closed-Loop Theory of Learning and Schmidt's (1975) Schema Theory (see *Table 1*). Each theory is dissected into two (Adams, 1971; Gentile, 1972; Schmidt, 1975) or three (Fitts & Posner, 1967) stages of learning. Fitts and Posner (1967) explained learning in three stages: cognitive, associative and autonomous. The cognitive stage requires the learner to focus on understanding the skill. The associative stage requires the learner to practice the skill and refine the movement pattern to complete the skill. The autonomous stage is reached or achieved when the learner can master the skill and develop consistency in performance. Gentile's (1972) model involves two stages: getting to know the idea and fixation/diversification. This first stage is very exploratory and requires a great deal of cognitive thinking. The learner investigates their actions or movements and creates a motor plan to address the issue they are presented with. Fixation/diversification is the skill refinement stage; the learner can refine the closed skills and diversify to transfer to open skills. Adams' (1971) theory is built on the concept of a perceptual trace and a memory trace. As we learn a skill, we develop a perceptual trace referring to the memory of successful past movements. To recall the perceptual trace, a memory trace is responsible for the choice and

initiation of the action. Schmidt (1975) elaborated on Adams' (1971) theory explaining recognition memory and recall memory are more accurate terms for perceptual trace and memory trace respectively, as they are more generalizable. The more generalized schema commonly referred to as a generalized motor program (GMP) allows for adjustment during both stages even if the learner has not experienced the exact situation, as the GMP can produce a whole class of movements opposed to one particular movement. If the learner knows the desired movement, previous experiences of similar tasks allow the learner to adjust the movements due to developments in the central nervous system (Schmidt, 1975). While stages are defined in each of the various theories, learning is a continuous process that results in gradual shifts between stages (Fitts, 1964; Schmidt, 1975; Gentile, 1972; Luft & Buitrago 2005). Luft and Buitrago (2005) further explained that people spend the most time in the acquisition phase of a skill (associative or first stage of most learning theories), as motor learning is usually acquired over several training sessions and requires repetitive training. The timing or transition from stage to stage is dependent on the learner and the task complexity. Motor skill learning is measured by the improvement of performance scores (McMorris, 2004). Common methods used to infer motor learning is to measure motor performance through retention test, transfer test or performance curve (McMorris, 2004). The learning theories discussed provide an over-arching summary of learning, however, the motor memory processes provides an understanding of motor skill acquisition through the creation of a motor memory. This leads into the next section that will discuss the processes of creating a motor memory.

### **2.1.2 Motor Memory Processes**

The formation of a motor memory is important for the production and replication of a motor skill. Three interdependent processes are involved in creating a motor memory; including encoding, consolidation, and retrieval (Kantak & Winstein, 2012; Robertson & Cohen, 2006; Walker & Stickgold, 2006). Encoding is the creation of a motor memory that occurs primarily during the acquisition or practice of a motor skill (Kantak & Winstein, 2012) and is highly susceptible to interfering influences or decay (Rasch & Born, 2013). In the encoding phase, learners may experience various practice variables such as observational learning, physical practice and feedback that help facilitate learning. Feedback is used to update the motor memory to improved performance on future trials (Kantak & Winstein, 2012). For example, when an individual is trying to learn a gymnastics routine, they extract relevant movement information from the practice variables such as order, timing and directions of the various movements in the routine to perform the routine correctly. Therefore, the extracted relevant information from the practice variables is used to create a motor memory of the task to be performed in the future.

Consolidation is the process responsible for integrating the encoded memory representation into existing brain networks and is stored in long-term memory (Kantak & Winstein, 2012). During the consolidation phase, relevant information is separated from non-relevant information, which helps facilitate a stronger mental memory of the motor skill (Kantak & Winstein, 2012). Developments in motor learning have shown that potential differences in consolidation can be influenced by

variables such as sex of the learner (Dorfberger, Adi-Japha & Karni, 2009) and sleep (Trempe & Proteau, 2012; Walker & Stickgold, 2006; Wilhelm, Diekelmann, & Born, 2008).

Retrieval is the process responsible for accessing and recalling the stored memory trace that was encoded and consolidated. For example, remembering names of people you have met, places you have visited or recalling motor skills learned in the past. The only possible measure of memory and learning is retrieval; a retention or transfer test can be conducted to determine if one effectively encoded, consolidated and retrieved the relevant information when practice variables are removed (Kantak & Winstein, 2012; Trempe & Proteau, 2012).

Every time a memory is recalled, the interaction between encoding, consolidation, and retrieval occurs. Once recalled, the memory is recoded. However, the memory is reinforced and strengthened each time it is recalled and encoded (Kantak & Winstein, 2012). The consolidation and retrieval processes are a function of the practice contexts experienced during the encoding phase; the better the practice or acquisition, the greater the consolidation and the better the retrieval (Kantak & Winstein, 2012). For a memory representation to be useful, the learner must be able to retrieve the information that was encoded and consolidated. The creation of a motor memory can be affected by many variables, which leads into the next section.

### **2.1.3 Challenge Point Framework**

The challenge point framework (CPF) explains that learning is related to the relationship and interactions of information available, motor task difficulty and



performer's skill level. Practice is the most important factor for learning a motor skill; however, according to the CPF, practice is only beneficial if the information available is presented to the learner in an interpretable form (Guadagnoli & Lee, 2004). When information is available, there is potential for learning to occur as information is seen as a challenge for the learner. Three important corollaries have been identified from this theory: (a) learning cannot occur in the absence of information, (b) learning will be hindered if too much or too little information is presented, (c) an optimal amount of information needs to be present for learning to occur, which differs as a function of skill level and task difficulty (Guadagnoli & Lee, 2004, pg. 213). The concept of task difficulty is difficult to explain using an encompassing definition, and therefore, is divided into two broad categories: nominal difficulty and functional task difficulty. The nominal difficulty is the constant amount of task difficulty (consistent characteristics of the task) irrespective of the individual or conditions in which the task is learned (Guadagnoli & Lee, 2004). Functional task difficulty refers to how challenging the task is based on the learner's skill level and the conditions in which the task is learned (Guadagnoli & Lee, 2004). As the functional task difficulty increases, so does the amount of information available. Ultimately, increasing the functional task difficulty extensively would provide the most interpretable information available; however, a performance learning paradox exists as learners have a limit to the amount of information they can interpret (Guadagnoli & Lee, 2004). Therefore, the CPF encompasses information available, skill level and task difficulty to create an optimal challenge point for learning.

#### **2.1.4 Motor Skill Acquisition**

The development of motor skills and specific movement patterns is important for sport and everyday life situations. For such skills, technique is typically crucial to improve performance and avoid injury (Herbert & Landin, 1994). Motor skill development is affected by many other variables not discussed above including, but not limited to, the scheduling of practice conditions, the delivery of augmented feedback, and the use of demonstrations (Rendell, Masters, & Farrow, 2009). The scheduling of practice conditions is known as contextual interference (CI) and was first studied by Battig in 1972. Battig (1972) postulated that interference present during the learning of a task results in better retention and transfer of skills. Shea and Morgan (1979) conducted a study further developing Battig's notion of skill acquisition through retention and transfer assessments. High levels of CI (random practice) showed greater retention and transfer assessment scores than the low levels of CI (blocked practice). Low CI only showed greater improvements during the acquisition phase of learning. It is found that high levels of CI can overwhelm learners in the early stages of skill acquisition; a base of skill may need to be acquired through blocked practice before the benefits of random practice can occur (Rendell et al., 2009). This information is also in line with research produced by Vickers (2011), Williams & Hodges (2004), and Lee, Swinnen & Serrien (1994).

Augmented feedback is an important aspect of skill acquisition; it is the action of receiving information during or after the completion of a task (Rendell et al., 2009). If feedback is provided in an appropriate manner, skill acquisition can

improve significantly (Schmidt & Lee, 1999). If too much feedback is given to the participant, it can interfere with performance as the participant relies too much on external feedback and less on internal feedback (Salmoni, Schmidt, & Walter, 1984). The use of internal feedback is important, as the participant has to use error-detection and correction senses to improve their skills throughout practice. As one improves at a particular skill, less external feedback should be given, and more focus on internal feedback should occur. Practice variables that stimulate instead of obstruct the use of the individual's cognitive processes during acquisition are viewed as advantageous to learning (Rendell et al., 2009). Age and maturation also play a role in skill acquisition; however, these variables cannot be altered or adjusted (Vickers, 2011).

The use of demonstrations, typically through modeling has proven to be a viable method that facilitates motor skill acquisition. Studies have shown that demonstrations improve acquisition of a motor skill (Guadagnoli, Holcomb & Davis, 2002; Herbert & Landin, 1994). Within demonstrations, many variables can be manipulated regarding the model. This leads into the next section that will discuss in detail the theory behind observational learning, variables within observational learning that affect motor skill learning and the types of skill typically investigated through observational research.

## **2.2 Observational Learning**

Observational learning facilitates learning of a motor or cognitive skill. Demonstrations have been found to be a successful observational learning method in the acquisition of various motor skills (see Hodges, Williams, Hayes, & Breslin,

2007; McCullagh, Weiss, & Ross, 1989; Ste-Marie, 2013, for reviews on observational learning). Through demonstrations, the observer is provided with a dynamic display of the goal movement that can be further enhanced through physical practice (Andrieux & Proteau, 2013; Wulf & Mornell, 2008). This section will discuss the theory behind observational learning, observational learning variables that affect skill acquisition, skill classifications typically investigated (fine, gross, simple and complex) and the combination of physical practice and observational learning.

### **2.2.1 Social Learning/Cognitive Theory**

Bandura's (1969), social learning theory states that human behaviour is learned through social interaction within an environment. In the absence of physical practice, one can observe the actions of others resulting in the development of a cognitive or motor skill. While the learning theories discussed in section 2.1.1 (Adams, 1971; Fitts and Posner, 1967; Gentile, 1972; Schmidt's, 1975) require physical practice to acquire skill, the social learning theory explains how humans acquire skills through observing a model in the absence of physical practice (Bandura, 1977). The social learning theory suggests using a model is an effective way to convey information and initiate skill acquisition before performing, as one can gain knowledge of the skills, strategies and rules used when completing a task (Ferrari, 1996). This would allow for the observer to create a mental model of how to produce the desired outcome by organizing response components to produce the behaviour that was observed (Bandura, 1977). Bandura (1986; 1977) describes four

constituent processes required for acquiring new skills through observation: attentional, retentional, reproduction and motivational.

The attentional process determines what important information presented by the model is relevant and perceived by the learner. Exposure alone to a model does not mean the learner will pay close attention to a model, extract relevant characteristics of the movement or observe accurately what is occurring (Bandura, 1977). It has been stated that observing a model with interesting and attractive qualities usually gains the attention of observers over models that display unpleasant characteristics (Bandura, 1977). For example, when observing gymnasts, a person who can manipulate their body and perform a routine with precision and accuracy of each move catches the attention of observers compared to a gymnast who is less coordinated and fluent with their movements. With superior knowledge and cognitive skills, observers can recognize subtle differences that may not be distinguishable to the untrained (Bandura, 1986).

The retentional processes are important in coding and organizing the relevant behaviours perceived by the learner. For an observation to be useful, the relevant information must be retained in memory, symbolically coded and reinforced through cognitive rehearsal (Bandura, 1986). Symbolically coding is the ability to represent an observed behaviour in symbolic form that can be used as a guide for future reproduction of similar behaviours. Learners can code information in a variety of forms including pictorial images, descriptive words or linguistic constructions. Storing information in symbolic form provides the learner with a great deal of information (Bandura, 1986). During this process, repetition can

enhance the memory code by increasing the strength of the code when information is still available in immediate memory.

The reproduction process determines the ability of the learner to recall and produce the learned modeled behaviour from the symbolic coding (Bandura, 1986). The reproduction process improves with increased observational practice. To understand the amount of observational learning that occurred, one can measure the ability to recall an observed behaviour through retention or transfer tests. When one possesses the essential characteristics of a movement, integration and production of the learned behaviour is easily produced. If one lacks the essential characteristics of the behaviour, reproduction will be flawed (Bandura, 1977).

The motivational process determines if the observed action acquired will be useful to the learner and used in the future. If the action is of value to the learner, they are more likely to complete the action compared to an action that has little functional value or one that has unrewarding or punishing effects. Furthermore, when incentives are present such as a reward for good behaviour, observation quickly becomes action, as one is more likely to pay attention and retain the information presented (Bandura, 1977; 1986). Therefore, the observation of a model facilitates the use of all four sub-processes as they are all interconnected.

### **2.2.2 Observational Learning Variables**

Demonstrations presented by models are the most frequently used method of conveying information to learners especially in the context of sport (Bandura, 1977; Bandura 1986; Williams & Hodges, 2005). However, researchers have attempted to determine what skill level of model is best for learning: skilled or

unskilled. Top-level athletes or expert models that provide the correct technique were originally used as demonstrators for live demonstrations and instructional videos because they were believed to facilitate the most accurate representation of the required movement pattern (Lee et al., 1994). However, the use of novice models or learners practicing the skill has also been supported. Which skill level elicits a greater improvement through observational learning has produced mixed results over the years. Evidence has supported the use of unskilled models (Black & Wright, 2000; Mattar & Gribble, 2005; Meaney, Griffin, & Hart, 2005; Pollock & Lee, 1992) and skilled models (Bird & Heyes, 2005; George, Feltz, & Chase, 1992; McCullagh, et al., 1989; Rohbanford & Proteau, 2011) as ways to improve skill acquisition through observational learning. Novice models provide an initial idea of the movement and encourage learners to use error detection and correction skills to refine the movement (Blandin, Lhuisset & Proteau, 1999; Blandin & Proteau, 2000). Expert models demonstrate correct strategies of how to perform the motor skill that encourage acquisition of the required movement pattern to complete the motor skill (Buchanan & Dean, 2010; Patterson & Lee, 2008, Ste-Marie, 2013). Recent research has found that a mixed observation schedule of intermixing novice and expert models enhances the benefits of using demonstrations (Andrieux & Proteau, 2014; Blandin Lhuisset, & Proteau, 1999; Rohbanfard & Proteau, 2011). Theoretically, mixed models facilitate learning through observation of an accurate template of the action as well as encourage error detection and correction mechanisms. Overall, when learning a skill, observations of either model provide the learner with an opportunity to extract important information from the model and use this

information to produce the desired action; however, these benefits are dependent upon the skill level of the learner and the task complexity.

Dyadic training is a method whereby two participants alternate between observing and physically practicing the skill, typically involving two novice or unskilled participants. The use of observational learning through dyadic training has proven to be an efficient and cost-effective strategy to learning new motor skills through dyadic training (Shea, Wulf, & Whitacre, 1999; Shebilskem, Regian, Arthur, & Jordan, 1992; Wulf, Shea & Lewthawite, 2010). Shebilskem et al., (1992) investigated the effect of using active interlocked modeling (AIM), a dyadic protocol, compared to individual-based training on skill acquisition. Participants in the AIM-dyad group practiced alongside their partner with one controlling the mouse and one controlling the joystick, exchanging roles every other practice game. The individual group practiced by themselves. Results showed resources and trainer time were halved for those in the dyad condition compared to participants in the individual group when learning a video-game (Shebilskem, et al., 1992). Sanchez-Ku and Arthur (2000) later replicated Shebilskem et al., (1992) research determining that dyad learning was generalizable to female participants. Dyad learning is suggested to increase motivation, achieve higher goals due to competition with partner, decrease fatigue due to alternating between observation and physical practice, and increase social interaction (Sanchez-Ku & Arthur, 2000; Shebilskem et al., 1992; Shea et al., 1999; Shea et al., 2000; Wulf et al., 2010). Similar to dyad learning, Martineau, Mamede, St-Onge, Rikers, and Schmidt (2013) investigated the acquisition of physical examination skills in a group setting compared to an



individual setting. When given the opportunity to observe a peer during practice, participants performed significantly better than students who did not. One limitation of the study is that the observed effects may be a result of interaction between participants throughout the observation (Martineau et al., 2013). Both dyad learning and group learning has potential to improve skill acquisition of various skills in an efficient and cost-effective strategy.

The timing of demonstrations is also important when considering the use of observational learning. Weeks and Anderson (2000) manipulated the timing of demonstrations of a volleyball serve using three groups: before, during, and a combination of before and during. The group receiving the combination of demonstrations before and during resulted in more accurate movements followed by the all before practice group. Weeks and Anderson (2000) postulated the group viewing the model during practice relied too much on the demonstrations as a video clip was shown every third attempt. When assessed on retention and transfer tests, they could not re-create the skills as accurately without the demonstration being present. Although a significant amount of research has been conducted in motor learning using demonstrations, there is a lack of research on the timing of when to provide demonstrations to the learner. A possible explanation for this might be that observation mixed with physical practice shows positive results in learning a motor skill; therefore the exact time to provide the demonstration is overlooked. Future research should investigate whether the timing of observation matters when mixed with physical practice.

Demonstrations are typically provided in two medias, live or video. Only a few studies have specifically addressed which type of demonstration is better for learning (Reo & Mercer, 2004; Rohbanfoard & Proteau, 2013). Results from these two studies demonstrate a person can learn a motor skill through live or video demonstrations. No significant differences were found between live and video demonstration scores in learning an exercise program (Reo & Mercer, 2004) or performance on a barrier knock down task (Rohbanford & Proteau, 2013), however, video demonstrations have the added benefit of convenience, consistency and efficiency. A video demonstration allows many participants to watch the exact same demonstration at different times and in different places.

### **2.2.3 Types of Skills**

Many observational learning studies have investigated the effects of the acquisition of fine motor skills such as assessing finger tapping (Bird & Heyes, 2005; Shea et al., 2000) or a relative timing pattern (Andrieux & Proteau, 2014; Blandin et al, 1999; Rohbanfard & Proteau, 2011; Rohbanfoard & Proteau, 2013), with less of a focus on gross motor skills. Gross motor skills are used in everyday life such as walking or running, but also important skills that athletes require to use in their sport such as stickhandling and dribbling while in motion. Wulf and Shea (2002) conducted a review comparing observational learning of simple and complex skills. Simple skills are generally defined as skills that can be learned in a single session and require minimal cognitive ability. Conversely, a complex skill typically cannot be learned in a single session, has multiple degrees of freedom, meaning there are many ways to perform the same movement to achieve the goal, and require

increased cognitive effort to learn the skill (Wulf & Shea, 2002). Research has investigated the effects of observational learning of simple skills and has found equivocal results. Some research has found no effect while other research has found observational learning to be effective for simple skills (Bird & Heyes, 2005; Blandin et al, 1999; Lee & White, 1990). Observational learning has also demonstrated that modeling is an effective way to improve the accuracy of complex skills (Reo & Mercer, 2004; Shea et al., 1999; Sidaway, & Hand, 1993). Wulf and Shea (2002), postulate three reasons why learning complex skills through observational learning can be effective: (a) Complex skills have physically more to observe, as there is an increase in motor requirements to complete the motor skill. (b) Complex skills allow the learner to engage in cognitive processing to create a motor plan for the movement. (c) Due to the complexity, observation can be interspersed with physical practice during rest intervals, as most complex skills are physically demanding (Shea & Wulf, 2002). Observation of complex skills also provides an overall picture of how all the components of the skill fit together (Wulf & Mornell, 2008). Therefore, complex skills have the potential to be learned more effectively through observational learning due to a complex motor pattern that takes much longer to acquire compared to simple skills that can be easily acquired through minimal practice. Although observational learning has demonstrated that modeling is an effective way to improve performance proficiency/accuracy of complex skills, little is known about the effects of observational learning on complex gross motor skills requiring full body movements in relation to improving speed and competency of a sport-specific skill.

#### **2.2.4 The Combination of Physical Practice**

Physical practice is the most important element in learning a motor skill; however, the addition of observational learning to physical practice has generally resulted in greater improvements than either practice regimen alone (Andrieux & Proteau, 2013). Commonly, “demonstration followed by imitation” is a viable method that is used when learning motor skills (Wulf & Mornell, 2008). Other studies have also found positive results with the combination of physical practice interspersed with observational learning (Deakin & Proteau, 2000; Laguna, 2008; Shea, Wright, Wulf, & Whitacre, 2000). Despite limited research on this topic, observational learning has been found to be beneficial early in practice as it allows the learner to extract important information that would be difficult to extract through physical practice. Many of the results indicate that observational learning is beneficial to motor skill learning, however physical practice alone has resulted in superior scores in retention and transfer tests compared to observational learning alone (Boutin, Fries, Panzer, Shea, & Blandin, 2010; Ellenbueger, Boutin, Blandin, Shea, & Pazer, 2012; Shea et al., 2000). Therefore, one cannot master a motor skill solely through observation since one needs a movement repetition to experience sensory consequences of the action to update the motor memory of that skill (Trempe, Sabourin, Rohbanfard, & Proteau, 2011).

#### **2.3 Hockey Demands**

In the realm of hockey, technical skills such as skating, shooting, passing, and stickhandling and puck control skills (SPC) skills are fundamental to the game. Research in the sport of ice hockey has primarily been dedicated to investigating the

physiological demands of game performance (Cox, Miles, Verde & Rhodes, 1995; Montgomery, 1988; Twist & Rhodes, 1993a; 1993b), the biomechanical analysis of skating (Fortier, Turcotte & Pearsall, 2014; Upjohn, Turcotte, Pearsall & Loh 2008) and shooting (Lomond, Turcotte & Pearsall, 2007; Michaud-Paquette, Pearsall & Turcotte, 2009; Pearsall, Montgomery, Rothsching & Turcotte, 1999) and off-ice hockey performance predictors (Behm, Wahl, Button, Power & Anderson, 2005; Burr et al., 2008; Farlinger, Kruisselbrink & Fowles, 2007; Potteiger, Smith, Maier & Foster, 2010).

Despite being a fundamental skill, limited research has been conducted on SPC skills in ice hockey. The research conducted on SPC skills includes on-ice research conducted by Stark, Tvoric, Walker, Noona and Sibla (2009) and off-ice, unpublished master's research conducted by Komenda (2010). Stark et al., (2009) examined the effects of practicing with a weighted puck for the first 10-15 minutes of practice. Results revealed an improvement in grip strength. However, stickhandling ability did not reach statistical significance, but did show a positive trend in stickhandling ability. Two major limitations of the study include stickhandling accuracy was not assessed during testing and the weighted puck was added for conditioning drills at the beginning of practice, not specifically designed SPC drills. Komenda (2010) assessed SPC skills using normal and restricted vision during training. Results revealed both simple and complex SPC skills showed significant improvement with the training sessions excluding normal vision when completed after restricted vision (Komenda, 2010). Overall, improvements in skill were a result of training volume opposed to order of training (Komenda, 2010). The

findings from the two studies show positivity for improving SPC skills using various training systems both on and off the ice. Stark et al., (2009) postulate skills such as gliding, stickhandling and moving against players are difficult skills to re-create off-ice, therefore, these types of skills are better learned and practiced on-ice.

Time-motion analyses have found that the overall average time (s) a player possess the puck during a game between the levels of novice and pro is 47 seconds (Kingston, 2014) despite the average player being on the ice for 17.6 minutes. Some players, especially in youth hockey never even touched the puck. USA Hockey (2002) investigated puck possession of the three top offensive players at the 2002 Olympics in Salt Lake City. Results revealed that the average minor hockey player only possessed the puck for 67.1 seconds during a game compared to Joe Sakic an NHL player who possessed the puck for 79.5 seconds. USA Hockey (2002) continued to investigate puck possession at the levels of Pee Wee, Bantam, and Midget at the National Championships. Results revealed that no player possessed the puck for more than 110 seconds with the average time of possession 38.4s, 56.2s, and 48.3s respectively. Players under the age of 8 typically only possess the puck for an average of 15-20 seconds meaning more than 180 games would be needed for a player of this age to possess the puck for 60 minutes; the typical length of a practice (Kingston, 2014). Findings from these studies suggest that games do not provide players with enough puck possession time to develop fundamental SPC skills, which support technical skills being developed through repetition.

The majority of information available on SPC skills is through practitioner or coach focused articles on how to coach/teach SPC skills. These articles have an

abundance of tips, techniques, and drills to improve SPC skills. However, the majority of the information is in regards to off-ice training, as it is more cost-effective and can be practiced anywhere. Practitioner articles that address on-ice practicing of SPC skills use the same tips and techniques as the off-ice training, but players can also work on pivots and tight turns around pylons to help with tight space SPC skills that are generally harder to practice when off ice due to the practice surface.

## 2.4 Purpose

The purpose of the study is to compare the effectiveness of two sport-specific training methodologies using a novel SPC training device; physical practice (PP) and physical practice and observational learning (PP+OL), on skill acquisition and retention of SPC skills in competitive hockey players.

## 2.5 Null and Alternative Hypotheses

Effect of training intervention on execution time or execution competency.

$$(a) H_0: M_{Apre} = M_{Apost}$$

$$(b) H_1: M_{Apre} \neq M_{Apost}$$

Interaction of training group (PP and PP+OL) on execution time across three repeats ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ), measured in seconds (s).

(a)  $H_0$ : There will be no significant interaction between training group execution time across the three repeats.

(b)  $H_1$ : There will be a significant interaction between training group execution time across the three repeats.

Main effect of execution time across the three repeats ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ).

$$(a) H_0: M_{A_{pre}} = M_{A_{post}} = M_{A_{ret}}$$

$$(b) H_1: M_{A_{pre}} \neq M_{A_{post}} \neq M_{A_{ret}}$$

Main effect of training group (PP or PP+OL) on execution time measured in seconds (s).

$$(a) H_0: M_{PP} = M_{PP+OL}$$

$$(b) H_1: M_{PP} \neq M_{PP+OL}$$

Interaction of training group (PP and PP+OL) on execution competency across three repeats ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ), measured using a score of 0-48.

(a)  $H_0$ : There will be no significant interaction between training group execution competency across the three repeats.

(b)  $H_1$ : There will be a significant interaction between training group execution competency across the three repeats.

Main effect of execution competency across the three repeats ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ).

$$(a) H_0: A_{pre} = A_{post} = A_{ret}$$

$$(b) H_1: A_{pre} \neq A_{post} \neq A_{ret}$$

Main effect of training group (PP or PP+OL) on execution competency measured using a score of 0-48.

$$(a) H_0: M_{PP} = M_{PP+OL}$$

$$(b) H_1: M_{PP} \neq M_{PP+OL}$$

## 2.6 Significance of Study

Information gathered from the study will allow for further understanding of the effectiveness of combining infrastructure and expertise in sport-specific training



methodologies. It will provide us with knowledge to determine effective SPC training methodologies.

## CHAPTER 3: METHODOLOGY

**3.1 Participants**

Male (N=40), atom-aged (2005; 2006 birth years for the 2016/2017 playing season;  $10.15\text{yrs} \pm 0.77\text{yrs}$ ) hockey players were recruited to participate and assigned to one of the three groups; PP (n=16), PP+OL (n=15) and control (n=9). Players were assigned to groups based on player and ice time availability. Participation was limited to the playing positions of forward and defense and players currently injury free. Participant assent and parental/guardian consent was obtained before participation in the study (Appendix D). This project received ethical clearance by the Brock University Research Ethics Board (File # 15-198).

**3.2 Study Design**

An experiment was conducted to compare the effectiveness of two methodologies using a novel approach to SPC training on execution time(s) and execution competency (rating) of select SPC skills. All groups completed one 50-minute familiarization session and two assessment sessions [pre-training ( $A_{\text{pre}}$ ) and post-training ( $A_{\text{post}}$ )] consisting of off- and on-ice assessments. The PP group received eight 50-minute on-ice SPC training sessions. The PP+OL received the same on-ice training, plus an additional 10 minutes of observational learning prior to each on-ice session (*Table 2*). Only the PP and PP+OL groups completed a third assessment session following two-weeks of no SPC training to assess retention ( $A_{\text{ret}}$ ). The control group did not receive the intervention training or the retention assessment. Study timelines are illustrated in *Figure 1*.

### 3.3 Familiarization Protocol

All participants completed one 50-minute training session introducing the five specific SPC drills that were included in the three assessment sessions. Each drill was introduced verbally by name and verbal instructions by a skilled instructor accompanied a live-demonstration by a skilled instructor. Participants were allowed to ask questions at the completion of the demonstration.

### 3.4 Assessment Protocol

Assessment sessions were scheduled and conducted: pre-training intervention ( $A_{pre}$ ), post-training intervention ( $A_{post}$ ) and following a two-week break to assess retention ( $A_{ret}$ ). The assessment sessions included off- and on-ice assessments batteries as detailed below. The order of assessments and the researchers conducting the assessments remained consistent across all three assessment sessions.

**Off-ice assessments:** The off-ice assessment consisted of two anthropometric measurements: height (cm) and weight (kg), and a modified Aggiss and Walsh (1986) coordination assessment. The modified Aggiss and Walsh (1986) field hockey coordination assessment required the player to move a puck with their own hockey stick from left to right across a measured distance of 0.61 m (2 feet) on an artificial ice surface board as many times as possible for 30 seconds. The total number of successful repetitions from left to right and right to left in 30 seconds was recorded. Successful repetitions were defined by any part of the puck touching the line on either side of the board, while continuously moving the puck from side to

side. Participants completed two trials with a 3-minute rest period between trials. The best trial was used for the purpose of statistical analyses.

**On-ice assessments:** Participants wore full equipment and were told to have skates sharpened for game-like conditions based on personal preference. A standardized warm-up included a 5-minute free skate where players could skate and warm up with the puck individually. The on-ice assessment battery consisted of two forward skating drills and five selected SPC drills<sup>1</sup> (Drills are listed in Appendix E). The first skating drill was repeated twice to assess the reliability of the player's performance. Participants were fitted with a small wireless device known as a Radio Frequency Identification (RFID) tag to individually identify each participant within the software recording system. A Swift™ timing light system measured device interval time (4 devices, D1, D2, D3, D4; s) or the time to execute the skills through each device and execution time (s) to complete four devices (total time) (See *Figure 2*). If a player failed to complete the drill completely (e.g., falls, breaks a timing light prematurely, etc.), a player received a “did not finish” (DNF), meaning a score was not recorded for the attempt and the player was asked to repeat the drill until successfully completed. A complete list of DNF criteria is listed in Appendix H.

Execution competency was assessed upon completion of each of the five SPC drills using a 12-point scale for each device within the drill. A score of 0-3 was assigned for each of the four criteria based on the participant's performance for each device within a drill.

- A score of 0 represents execution of the device with no mistakes

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<sup>1</sup> The industry partner has identified the SPC drills for the purpose of this assessment.

- A score of 1 represents execution of the device with 1 mistake
- A score of 2 represents execution of the device with 2 mistakes
- A score of 3 represents execution of the device with 3 or more mistakes in a category.

The rating scale consisted of four criteria per device: 1. mishandle of the puck, 2. loss of puck, 3. body hits device, and 4. puck hits device.

- A mishandle of the puck is represented by a player fumbling the puck within the stick's range or motion while staying on the desired path of the drill.
- Loss of the puck is represented by a player losing control of the puck and having to go off the desired path of the drill.
- Body hits device is represented by any part of the participant including the stick touching the device at any time during the drill.
- Puck hits device is represented by the puck touching any part of the device during the drill.

An overall score out of 12 was then recorded for each participant on each SPC device with 0 representing superior execution competency to 12 representing no execution competency per device. Therefore, each drill had a possible total score out of 48.

All participants' performances were rated by the same expert rater across all three assessment sessions. Verbal encouragement was provided throughout all assessment sessions to promote maximal effort on assessment drills.

### 3.5 Training Intervention

#### 3.5.1 Physical Practice Group (PP)

The PP group completed a SPC training intervention consisting of eight 50-minute training sessions, scheduled twice a week for four weeks. Training sessions consisted of a five-minute warm-up, 40 minutes of SPC practice, and five minutes of mini team SPC challenges (e.g. relay races) or a mini-game (e.g. keep away with the puck), incorporating the same SPC skills introduced during the practice. The first training session consisted of a set of five core drills. These drills focused on a set of skills, such as close and wide stickhandling, crossovers, balance control, pivots, and tight turns, which provided the foundation for more advanced drills. For training, a circuit-like pattern consisting of eight devices was used; four devices on each side of the ice were used for the majority of the drills (*Figure 2*). Repeating previous drills and adding more drills that were more advanced achieved a progressive overload from session to session. Each subsequent session consisted of four or five previously learned drills and three or four new drills (Appendix G). For each newly introduced drill, the circuit was repeated three times (completion of 24 devices of the same skill set). For previously introduced drills, the circuit was repeated one-two times (completion of 8 or 16 devices). The newly introduced drills from session to session were also based on a progressive overload strategy and increased in complexity. For example, a simple drill may include two tight turns with two tactical touches, where as a more complex drill would be two tight turns, a crossover and power move resulting in 4 tactical touches. Furthermore, once the skills of the drill were acquired, space between the devices and/or increased distance at the start

challenged participants to increase speed and thus increased complexity of the drills. All training sessions, including the familiarization session were instructed by the same instructors who were highly experienced, trained individuals all exemplifying a great level of knowledge of SPC skills.

Both individual and group feedback including knowledge of performance (KP) through positive and constructive feedback was provided throughout the eight training sessions. An example of constructive KP feedback included knowledge on how to correct movement errors such as helping a player open their hips to complete MOF by telling the player to put the lead skate in a forward glide position and use the back leg to push off to the side where they placed the puck. Positive KP was provided when players were completed a skill with precise execution such as “great puck placement and retrieval” or “good work on using your back leg to power you around the device”.

### **3.5.2 Physical Practice and Observational Learning Group (PP+OL)**

The PP+OL group completed the same SPC training intervention as described in PP. However, in addition to PP, the PP+OL training group received observational learning in the form of 10 minutes of instructional videos before each training session. To facilitate this, a video screen was set up in the dressing room at the arena before each training session. The company provided all the videos used in the study through their iPad app. As a group, participants were required to watch each of the drills included in the prescribed practice before the on-ice session; totalling 7-8 drills before each session. Each video was 60-90 seconds in duration and repeated the drill 2-6 times. The video incorporated tips and techniques to complete each

skill properly and provided built-in pauses and slow motion to emphasize some skills. Nearing the end of the video, the full drill was completed in real time speed followed by the key points at the end of the clip. A highly advanced hockey player was the model used in each of the videos. Participants were encouraged to ask questions at the end of each drill video. Participants were exposed to a total of 80 minutes of observational learning over the course of the study.

### **3.5.3 Control Group**

Control group participants (n=9) completed the familiarization session, two assessments scheduled four weeks apart [ $A_{pre}$  and  $A_{post}$ ], however, received no formal SPC training or observational learning. Players were allowed to continue with their respective teams, including games and practices.

### **3.6 Adherence**

Due to the nature of the study, participant attendance was monitored and recorded. If a participant missed a training session, they were asked to attend a make-up session scheduled following the last on-ice training session prior to  $A_{post}$ . Failure to complete the make-up session resulted in the removal of the participant's data, although the participant was allowed to continue with the training sessions. Fifty players started the study, however due to various reasons throughout the study (e.g. illness, injury, or missed sessions) 10 players dropped out of the study, resulting in 40 participants completing the study. Of those 40 participants, 13 players required a make-up session.



### 3.7 Statistical Procedures

Data was analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 23.0 (IBM, Chicago, IL). Descriptive statistics including mean ( $\bar{X}$ ) and standard deviation (SD) were calculated for all measures. A one-way Analysis of Variance (ANOVA) was conducted to determine if significant differences existed in age (months), height (cm), weight (kg), hockey experience (yrs) and coordination scores across the three groups (PP, PP+OL, and control) at A<sub>pre</sub>. A Pearson's product moment correlation was conducted between the two trials of the off-ice coordination assessment (# of successful repetitions) to assess the reliability of the player's coordination assessment scores. A two-way mixed Analysis of Variance (ANOVA) was conducted to identify if there was a significant difference in coordination scores between groups across the three assessments.

The on-ice skating and SPC drills were analyzed independently. Execution time of the skating drills was measured and execution time and execution competency of the SPC drills were measured. Stickhandling and Puck Control (SPC) data was analyzed by individual drill (five SPC drills) and combined overall total (COT; scores from all five SPC drills added together) for time and competency measures.

Pearson's product moment correlations were conducted to investigate the relationship between the first two forward skating drills with no puck (total time; s) in order to assess the performance reliability. A two-way mixed ANOVA was conducted to determine if significant differences existed in execution time between

training groups (PP and PP+OL) across the three repeats ( $A_{pre}$ ,  $A_{post}$  and  $A_{ret}$ ) on both skating drills independently.

Within-group paired samples t-tests were conducted to determine the effect of training from  $A_{pre}$ - $A_{post}$  for the training groups. Multiple two-way mixed ANOVAs were conducted to determine if significant differences existed in execution time (seconds) or execution competency (rating) between training groups (PP and PP+OL) on execution time (seconds) or execution competency (rating) across three repeats ( $A_{pre}$ ,  $A_{post}$  and  $A_{ret}$ ). If a significant interaction or significant main effects existed, a Bonferroni post-hoc test was conducted to determine where the differences existed. The above ANOVAs and t-tests were completed on combined overall total time (COTT) of all drills, combined overall total competency (COTC) of all drills, execution time of five individual drills and execution competency of five individual drills. Two-tailed paired samples t-tests were conducted to determine if significant differences existed in time and competency measures between  $A_{pre}$  and  $A_{post}$  for the control group. A within group repeated measures ANOVA was conducted to determine if there was a significant effect of interval times or interval competency scores across devices. An alpha level of  $p \leq .05$  was used for all statistical analyses.

## CHAPTER 4: RESULTS

**4.1 Subject Descriptives**

Male (N=40), atom-aged (2005; 2006 birth years for the 2016/2017 playing season;  $10.15\text{yrs} \pm 0.77\text{yrs}$ ) hockey players, were recruited to participate and assigned to one of the three groups; PP (n=16), PP+OL (n=15) and control (n=9). Player demographics including age (birth year), height (cm), weight (kg) and hockey and SPC training experience were collected and detailed in *Table 3* and *Table 4*.

Descriptive statistics revealed that 40% of players self-identified that they routinely practiced individual SPC skills on their own. That said, only 15% of the participants reported that they had limited exposure to the novel training device used for the purpose of the research. A one-way ANOVA revealed no significant differences in age (yrs), height (cm), weight (kg), or hockey experience at baseline between the two training groups. The control group however, was significantly older, currently playing at a higher level of hockey (AAA), had significantly more years of hockey experience, and reported practicing SPC skills on their own time more often than both training groups. Due to the significant differences in baseline measures, the control group was analyzed separately for the purpose of further statistical analyses.

**4.2 Off-ice Assessment**

Coordination assessment scores (Mean  $\pm$  SD) for both training groups across the three assessments ( $A_{\text{pre}}$ ,  $A_{\text{post}}$ , and  $A_{\text{ret}}$ ) are illustrated in *Table 5*. Pearson's product moment correlations revealed a significant strong positive linear

association between the two repeated coordination trials at each of the three assessments  $A_{pre}$  ( $r=0.86$ ,  $p < .001$ ),  $A_{post}$  ( $r=0.76$ ,  $p < .001$ ), and  $A_{ret}$  ( $r=0.96$ ,  $p < .001$ ), meaning that the number of successful repetitions was deemed repeatable indicating a reliable measure.

A two-way mixed ANOVA was conducted to determine if significant differences existed in coordination scores (# of successful repetitions) between groups across the three assessment sessions ( $A_{pre}$ ,  $A_{post}$  and  $A_{ret}$ ). The Greenhouse-Geisser ( $\epsilon=.81$ ) correction was used and revealed a statistically significant interaction between training groups and time on coordination scores,  $F(1.62, 47.05) = 8.893$ ,  $p = .001$ , partial  $\eta^2 = .02$ . Results revealed a significant difference in coordination scores between PP and PP+OL at  $A_{pre}$ ,  $F(1, 29) = 7.36$ ,  $p = .01$ , partial  $\eta^2 = .02$ . Coordination scores in the PP group ( $8.62 \pm 3.18$ ,  $p = .01$ ) were significantly greater than the PP+OL group at baseline. The PP and PP+OL groups did not differ at the  $A_{post}$  or  $A_{ret}$  assessment in coordination scores. There was a statistically significant within group simple effect of coordination score across the three assessment sessions for the PP group,  $F(2, 30) = 8.12$ ,  $p = .002$ , partial  $\eta^2 = .04$ , and the PP+OL group,  $F(2, 28) = 56.91$ ,  $p < .001$ , partial  $\eta^2 = .80$ . Bonferroni post hoc tests revealed coordination scores for the PP group were statistically different  $A_{pre}$ - $A_{ret}$  ( $M = 7.75$ ,  $SE = 2.33$ ,  $p = .01$ ) but were not significantly different between  $A_{pre}$ - $A_{post}$  ( $M = 3.69$ ,  $SE = 1.56$ ,  $p = .10$ ) and  $A_{post}$ - $A_{ret}$  ( $M = 4.06$ ,  $SE = 1.80$ ,  $p = .12$ ). The PP group improved coordination over the duration of the study. Bonferroni post hoc tests revealed coordination scores for the PP+OL group were statistically different  $A_{pre}$ - $A_{post}$  ( $M = 13.33$ ,  $SE = 1.32$ ,  $p < .001$ ) and  $A_{pre}$ - $A_{ret}$  ( $M = 16.73$ ,  $SE = 2.00$ ,  $p < .01$ )

but were not significantly different between  $A_{\text{post}}-A_{\text{ret}}$  ( $M = 3.40$ ,  $SE = 1.59$ ,  $p = .15$ ).

The PP+OL group improved coordination with training and maintained coordination after two weeks of no training.

A paired samples t-test revealed that there was no significant difference in coordination scores  $A_{\text{pre}}-A_{\text{post}}$  ( $p = .09$ ) for the control group.

### 4.3 On-ice Assessments

The skating drills included forward skating without the puck and forward skating with the puck. The SPC drills included; i) Stickhandling in Traffic (SIT), ii) Power-Turn (PT), iii) McDavid on the Fly (MOF), iv) Power-Turn Half-Crosby (PTHC), and v) Forward-Backward Transition (FBT). Drills were also analyzed based on overall drill complexity and were defined as simple or complex. The simple drills consisted of SIT, PT, and PTHC while the complex drills consisted of MOF and FBT.

Interval and execution time were measured for skating and SPC drills. Execution competency was also measured, however was only measured on the five SPC drills. The total times from the five individual SPC drills were added together to represent a combined overall total time (COTT). The total competency scores from the five individual SPC drills were added together to represent a combined overall total competency (COTC) score.

#### 4.3.1 Skating Assessments

*Table 6* and *Table 7* illustrate the means and standard deviations of the times to complete the on-ice forward skating assessment without and with a puck

respectively for both training groups across the three assessments. A Pearson's product moment correlation revealed a significant strong positive linear association between the two repeated forward skating drills without a puck  $A_{pre}$  ( $r=0.86$ ,  $p < .001$ ),  $A_{post}$  ( $r=0.87$ ,  $p < .001$ ), and  $A_{ret}$  ( $r=0.68$ ,  $p < .001$ ); meaning the times to complete the drill were deemed repeatable indicating a reliable test.

A two-way mixed ANOVA revealed no significant difference between training groups across time ( $A_{pre}$ ,  $A_{post}$  or  $A_{ret}$ ), meaning that both intervention groups did not see any differences in skating times with or without the puck.

This result was consistent in the control group. Paired sample t-tests revealed no significant differences in skating speed between  $A_{pre}$  and  $A_{post}$  for the control group meaning that skating speed with or without a puck did not improved over time.

#### **4.3.2 SPC Assessments**

Within-group paired sample t-tests were calculated to determine the effect of training on execution time (*Table 8*) and execution competency (*Table 9*) from  $A_{pre}$  to  $A_{post}$ . Results revealed significant differences in execution time  $A_{pre}$ - $A_{post}$  for the PP group for three of the five SPC drills and combined overall total time (COTT); SIT ( $p = .002$ ), MOF ( $p = .009$ ), PTHC ( $p = .029$ ), and COTT ( $p = .001$ ) and for execution competency on two of the five SPC drills: SIT ( $p = .006$ ) and MOF ( $p = .002$ ). Whereas PP+OL training only revealed significant differences in execution time  $A_{pre}$ - $A_{post}$  on one of the five SPC drills and combined overall total time; SIT ( $p = .001$ ) and COTT ( $p = .002$ ) but no significant differences in execution competency.

*Execution Time*

*Table 10* illustrates execution time (s) for all SPC drills (mean  $\pm$  SD). A series of two-way mixed ANOVAs were conducted to assess the effect of training group (PP and PP+OL) on execution time (s) of the five SPC drills across the three repeats ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ). No significant interactions were revealed for execution time for any of the five SPC drills or COTT. Significant main effects of execution time were revealed across the three assessments ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ) in three of the five SPC drills; SIT, MOF and PTHC, and COTT.

The main effect of execution time across the three assessments revealed a statistically significant difference in SIT at the different time points,  $F(2, 58) = 16.83$ ,  $p < .001$ , partial  $\eta^2 = .37$ . A pairwise comparison using a Bonferroni correction revealed that participants  $A_{post}$  execution time ( $3.71 \pm 0.65$ ,  $p < .001$ ) and  $A_{ret}$  execution time ( $3.09 \pm 0.80$ ,  $p = .002$ ) scores were both significantly faster than  $A_{pre}$  execution time scores. Both groups' time to complete SIT was almost four seconds faster after 8-sessions of SPC training and maintained following two-weeks of no SPC training.

The main effect of execution time across the three assessments revealed statistically significant difference in MOF at the different time points,  $F(2, 58) = 9.35$ ,  $p < .001$ , partial  $\eta^2 = .24$ . A pairwise comparison using a Bonferroni correction revealed that participants  $A_{post}$  execution time ( $2.46 \pm 0.70$ ,  $p = .005$ ) and  $A_{ret}$  execution time ( $1.92 \pm 0.50$ ,  $p = .002$ ) scores were both significantly faster than  $A_{pre}$

execution time scores. Both groups' time to complete MOF was 2.5 seconds faster after 8-sessions of SPC training and maintained following two-weeks of no SPC training.

The main effect of execution time across the three assessments revealed a statistically significant difference in PTHC at the different time points,  $F(1.58, 45.67) = 5.73, p = .010$ , partial  $\eta^2 = .17$ . A pairwise comparison using a Bonferroni correction revealed that participants  $A_{\text{post}}$  execution time ( $2.18 \pm 0.77, p = .024$ ) was significantly faster than  $A_{\text{pre}}$  execution time scores. The time to complete PTHC was two seconds faster after 8-sessions of SPC training but was not maintained following two weeks of no training.

A Mauchly's test of sphericity revealed that the assumption of sphericity was violated for COTT. The Greenhouse-Geisser ( $\epsilon = .770$ ) correction was used and revealed a statistically significant main effect of execution time across the three assessments in mean COTT,  $F(1.54, 44.63) = 17.80, p < .001$ , partial  $\eta^2 = .38$ . A pairwise comparison using a Bonferroni correction revealed that participants  $A_{\text{post}}$  execution time ( $11.19 \pm 2.00, p < .001$ ) and  $A_{\text{ret}}$  execution time ( $9.24 \pm 2.44, p = .002$ ) scores were both significantly faster than  $A_{\text{pre}}$  execution time scores. Both groups' time to complete all drills was faster after 8-sessions of SPC training and was maintained following two-weeks of no SPC training (*Figure 3*).

A paired samples t-test was used to determine if significant differences existed in execution time in the control group from  $A_{\text{pre}}$ - $A_{\text{post}}$ . No statistically significant differences in pre-post measures were revealed for any drill for execution time.



Multiple within-group repeated measures ANOVAs were conducted to determine if significant differences existed between interval times within a drill (s). Results from these ANOVAs were not statistically significant, suggesting no device was consistently faster or slower compared to the other devices.

### *Execution Competency*

*Table 11* illustrates execution competency scores for all SPC drills (mean  $\pm$  SD). A series of two-way mixed ANOVAs were conducted to assess the effect of execution competency between groups and across assessments ( $A_{pre}$ ,  $A_{post}$  and  $A_{ret}$ ) on the five SPC drills. No statistically significant interactions were revealed for execution competency for any of the five SPC drills or COTC (see *Figure 4* for COTC graph by group). Significant main effects of execution competency were revealed across the three assessments ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ) in only one of the five SPC drills (MOF). Significant main effects of execution competency were revealed between groups in only one of the five SPC drills (MOF).

The main effect of execution competency across the three assessments showed a statistically significant difference in the MOF drill at the different time points,  $F(2, 58) = 6.08$ ,  $p = .004$ , partial  $\eta^2 = .173$ . A pairwise comparison using a Bonferroni correction revealed that participants'  $A_{pre}$  execution competency ( $1.34 \pm 0.39$ ,  $p = .005$ ) and  $A_{ret}$  execution competency ( $1.22, 0.40$ ,  $p = .014$ ) scores were both significantly worse than  $A_{post}$  execution competency scores. Both groups were more competent after 8-sessions of SPC training but did not maintain competency following two-weeks of no SPC training.

The main effect of training group revealed a statistically significant difference in mean execution competency between the two training groups, during the MOF drill,  $F(1, 29) = 6.02, p = .02$ , partial  $\eta^2 = .17$ . Results of the analysis revealed that participants in the PP+OL ( $1.43 \pm 0.58, p = .02$ ) training group were significantly more competent than the participants in the PP group for the MOF drill.

A paired samples t-test was used to determine if significant differences existed in execution competency in the control group from  $A_{pre}$ - $A_{post}$ . No significant differences in  $A_{pre}$ - $A_{post}$  measures were revealed for any drill for execution competency.

Multiple within group repeated measures ANOVAs were conducted to determine if significant differences existed between competency scores of each individual device within a drill (12-point scale). Results from these ANOVAs were not statistically significant, meaning no device was consistently more or less competent compared to the other devices.

#### *Simple vs Complex SPC Drills*

Drills were broken down into simple (SIT, PT, and PTHC) and complex (MOF and FBT) drills for further analysis. The simple drills were drills that consisted of simpler skills such as tight turns and simple stickhandling (minimal tactical touches) while the complex drills required more complex skills such as open hips, pivots and quick change of directions.

Two, two-way mixed ANOVAs were conducted to assess the effect of training invention group (PP and PP+OL) between simple and complex drills across three

repeats ( $A_{pre}$ ,  $A_{post}$ , and  $A_{ret}$ ) on i) time (s) ii) execution competency. No statistically significant interactions were revealed for execution time or competency. A main effect of execution time across the three assessments was revealed for simple and complex skills. A main effect of execution competency across the three assessments was revealed for complex skills only.

The main effect of assessment showed a statistically significant difference in mean execution time at the different time points during the simple drills,  $F(2, 58) = 15.68, p < .001$  partial  $\eta^2 = .351$ . A pairwise comparison using a Bonferroni correction revealed that participants  $A_{post}$  execution time ( $7.01 \pm 1.32, p < .001$ ) and  $A_{ret}$  execution time ( $6.23 \pm 1.70, p = .003$ ) scores were both significantly faster than  $A_{pre}$  execution time scores. Both groups' time to complete simple drills was seven seconds faster after 8-sessions of SPC training and maintained following two-weeks of no SPC training (*Figure 5*).

The main effect of assessment showed a statistically significant difference in mean execution time at the different time points during the complex drills,  $F(2, 58) = 8.75, p < .001$  partial  $\eta^2 = .232$ . A pairwise comparison using a Bonferroni correction revealed that participants post execution time ( $4.40 \pm 1.22, p = .003$ ) and retention execution time ( $3.31 \pm 1.17, p = .025$ ) scores were both significantly faster than pre execution time scores. Both groups' time to complete complex drills was on average 4.4 seconds faster after 8-sessions of SPC training and maintained following two-weeks of no SPC training (*Figure 6*).

The main effect of assessment showed a statistically significant difference in mean execution competency at the different time points during the complex drills,  $F$

(2, 58) = 16.48,  $p < .001$ , partial  $\eta^2 = .362$ . A pairwise comparison using a Bonferroni correction revealed that participants  $A_{pre}$  execution competency ( $3.54 \pm 0.67$ ,  $p < .001$ ) and  $A_{post}$  execution competency ( $2.91 \pm .66$ ,  $p < .001$ ) scores were both significantly worse than  $A_{ret}$  execution competency scores. Both groups maintained their competency through the 8-training sessions and improved their competency following two weeks of no training (*Figure 8*).

A paired samples t-test was used to determine if significant differences existed in execution time or competency in the control group from  $A_{pre}$ - $A_{post}$  on simple or complex drills. A significant difference in execution competency was found  $A_{pre}$ - $A_{post}$  ( $p = .021$ ) for complex drills. Meaning participants were significantly more competent during  $A_{post}$ . No significant differences were found for execution time of simple or complex drills, or for execution competency of simple drills.

## CHAPTER 5: DISCUSSION

The purpose of the present study was to compare the effectiveness of two sport-specific training methodologies using a novel stickhandling and puck control (SPC) training device; physical practice (PP) and physical practice and observational learning (PP+OL), on skill acquisition and retention of SPC skills in competitive atom-aged hockey players. Effectiveness was defined as a significant improvement in execution time (s) and/or execution competency.

Typically, sport-specific hockey skills, such as skating, shooting and SPC skills are acquired through repetitive, structured physical practice as experienced during an on-ice, coach led practice. Physical practice has consistently been recognized as a significant contributor to learning a motor skill, as it allows the learner to constantly update and improve the motor memory of the skill (Andrieux & Proteau, 2013; Trempe, Sabourin, Rohbanfard, & Proteau, 2011). The effectiveness of physical practice can be influenced by a variety of controllable factors. For example, the type of practice, the practice environment, selection and progression of drills, overload stimulus, and quality of instruction, can all contribute to creating an optimal environment for skill acquisition and optimal learning. A learner-led, non-specific, practice void of technical instruction and skill or content progression may not create an optimal learning environment. Simply stated, stickhandling with a puck or ball in a driveway repetitively may not result in significant skill acquisition or transfer to a game-like situation if the learner is acquiring less than optimal technique and/or practicing in an environment that does not mimic game-like conditions. In addition, lack of technical instruction and progression can fall short of providing learners

with the stimuli or challenge to learn. Therefore, it could be assumed that the effectiveness of practice can be enhanced if participants engage in a structured on-ice practice with progressive overloads instructed by knowledgeable instructors. Practicing in game-like situations such as on-ice, in small spaces, with traffic also has the potential to better facilitate the transfer of the skill execution in practice to a game.

For the purpose of the study, a sport-specific SPC training system that packaged infrastructure (novel training device) and expertise (training methodologies) was implemented using learning theories to potentially optimize both the learning environment and proposed skill acquisition. All participants completed a total of 400-minutes of on-ice training. Both the number of drills and complexity of the specific drills defined the intensity of each training session. The number of drills was defined as the number of unique SPC drills, ranging from 6-9 per session over 8 sessions. The complexity of drills was measured by the number of tactical touches, defined by a player placing the puck under the training apparatus and moving the body and the stick to regain control of the puck, completed per drill. Drills ranged from simple to complex or 0-30 tactical touches per drill over 8 sessions. Total training volume was calculated by the number of unique SPC drill repetitions and sets completed per session multiplied number of tactical touches per drill. A progressive overload was implemented by increasing total training volume over the 8-session training intervention as defined above (See Appendix G). All instructors were highly experienced hockey players with a thorough knowledge

of SPC skills and provided players with individual and group feedback to ensure perfect practice.

It was predicted that the training intervention would optimally challenge the subject's ability and enhance overall SPC performance. Improvements in SPC performance were defined as a decrease in execution time (s) to complete each of the individual SPC drills while being able to maintain or increase the execution competency (rating) defined as the accuracy of performing the skill. Results of a within group  $A_{pre}-A_{post}$  analysis revealed that the participants' execution time (s) across all individual drills improved for both training groups; a decrease in time ranged from 0.5 seconds and 4.2 seconds, however, only isolated drills reached statistical significance. The PP group revealed significance on three out of the five drills and the PP+OL group one out of the five drills assessed, respectively. The same trend was not seen in executive competency; only the PP group revealed significant differences in execution competency on two out of the five drills which were two of the drills that execution time also reached significance for PP. When time was summed across drills (COTT), the pre-post analysis revealed a significant improvement for both training groups, however, when competency scores were summed across drills, (COTC), there was no significant difference for either training group (*Figures 3 and 4*).

The training invention elicited responses that were consistent with theories described or referred to as the CPF (Guadagnoli & Lee, 2004). Optimized learning occurs when skill level is appropriately challenged by task difficulty, by providing an optimal amount of interpretable task-related information for the learner

(Guadagnoli & Lee, 2004). The greater the functional task difficulty, the greater the learning potential, however, task difficulty must be appropriate to the level of the learner, as learners have a limit to the amount of information they can interpret. In both groups, it may be suggested that the on-ice training intervention challenged the learner with the appropriate task difficulty for their age and ability.

The modified Aggiss and Walsh (1986) coordination assessment was conducted to provide a baseline measure of the subject's upper body coordination. Both groups revealed significant improvement in coordination scores from  $A_{pre}$ - $A_{ret}$  (*Table 5*). That said, the PP group was significantly more coordinated at  $A_{pre}$  compared to their PP+OL counterparts. The magnitude of improvement on coordination scores was greater in the PP+OL group as reflected by their significant improvement from  $A_{pre}$ - $A_{post}$ , which resulted in no significant differences between training group coordination scores at the latter two assessments;  $A_{post}$  and  $A_{ret}$ . The addition of observational learning may have reduced the between training group differences that were revealed at  $A_{pre}$  as the coordination assessment was sensitive to this learning condition (observational learning); PP did not reveal a similar magnitude of change from  $A_{pre}$ - $A_{post}$ . It may be suggested that coordination or lack thereof, could have limited the magnitude of the training effect.

With respect to player's on ice improvement, as mentioned above, the PP group revealed improvements in execution time(s) on three out of five isolated drills and COTT from  $A_{pre}$ - $A_{post}$  compared to the PP+OL group only improving execution time on one out of five isolated drills and COTT. To explore these differences further, percent change or the magnitude of improvement was



calculated within each group for COTT. The PP group improved 10% from  $A_{pre}$  to  $A_{post}$  and the PP+OL group improved 8% from  $A_{pre}$  to  $A_{post}$ . The difference in improvement between groups might also be explained by the mean coordination scores pre training. The PP+OL group may have had an additional task of trying to develop their own coordination through the 8-session training intervention, which resulted in slightly lower percent change scores after training compared to the PP group.

In contrast to the PP training intervention where physical practice was in isolation, the PP+OL training intervention received an additional 10-minutes of observational learning each session, totalling 80-minutes of observational learning during the training study. It was anticipated that the observational learning would provide further stimulus for learning and skill acquisition. The observational learning was delivered in the form of multiple instructional videos watched in a group setting, immediately before each physical practice session. Results of the current study did not support the benefits of observational learning in combination with PP for execution time (s) or competency measures across the three assessments. In contrast to previous research suggesting that combining two learning methodologies has the potential to enhance skill acquisition, no significant differences between the two training interventions were found (Andrieux & Proteau, 2013; Deakin & Proteau, 2000; Laguna, 2008).

Potential reasons for the ineffectiveness of observational learning during the study may include but are not limited to age or cognitive maturity and focus of attention of the participants. The majority of the research investigating

observational learning used an older and more mature cohort of undergraduate students ranging in age from 17-24 years (Andrieux & Proteau, 2013; Deakin & Proteau, 2000; Laguna, 2008; Shea et al., 2000). Additionally, age and cognitive maturity of the learners may have played a factor in the non-significant findings as children are easily distracted and may not have been fully engaged in the videos as they were presented in a group setting. Finally, the videos may have provided too much information or what is referred to as, information overload for the learners to interpret and apply. A recent study suggested that if visual guidance is provided during observational learning such as highlighting important information in the video, it can accelerate motor skill acquisition of a complex motor skill (D'Innocenzo, Gonzalez, Williams, & Bishop, 2016). Without highlighting areas to focus on for the learners, participants were potentially provided with too much information and unable to determine and process the important information (D'Innocenzo, Gonzalez, Williams, & Bishop, 2016). Minimal visual guidance was provided throughout the some of the videos in the study through verbal instruction and quick clip pauses; however, visual guidance was sporadic, only lasted a few seconds per video and was not provided in all videos. Although the addition of observational learning prior to the on-ice portion of training did not have a significant additive effect on execution time or competency, it may be proposed that anecdotally observational learning seemed to have improved the organization and flow of the training sessions.

Skill retention was measured two weeks post training. No significant differences were found between  $A_{\text{post}} - A_{\text{ret}}$  in either training group. That said, there

was a limited decrement in motor skill performance over the two-week interval. Maintaining improvements after removing the training stimulus suggests that participants not only acquired the motor skills but also developed relative permanence in execution of the skills learned in training. This outcome is consistent with Kantak and Winstein's formation of a motor memory (2012). The training provided the players with the repetitions required not only to refine and acquire the SPC skills but also to automate the movements, that when the training stimulus was removed, they were able to retrieve the motor plan created during training and reproduce the SPC skills at a relatively similar speed and competency scores.

Further analyses of outcome measures, execution time (s) (speed) and execution competency (rating) (accuracy) were investigated to understand if a potential trade-off between speed and accuracy existed (Fitts, 1954). In the sport of ice hockey, this may be represented as puck speed versus accuracy of a shot. For example, a player who can shoot the puck hard but less accurate (misses net) still contributes good quality to the team, as does a player with great accuracy but a weaker shot. However, a player that has a hard and accurate shot has a better chance of scoring, which is the ultimate goal. A similar parallel can be seen in the trade-off between speed and accuracy of SPC skill execution. Players need to be able to skate fast while maintaining control of the puck. Therefore, analyzing time and competency results may provide a better understanding of the players overall SPC ability. Results of the study revealed an improvement or decrease in execution time (s) while maintaining execution competency; players were able to complete the drills at faster speeds while maintaining accuracy.

The training sessions and assessment battery were comprised of both simple and complex drills, which represented various skills a player would reproduce during game situations. A review compiled by Wulf and Shea (2002) contrasting the responses elicited by the type of drill revealed that simple drills require less practice and less cognitive ability to learn compared to complex drills that have an increased cognitive demand and require multiple training sessions to improve on the drill. In the present study, the five individual SPC drills were separated into simple (3 drills) and complex (2 drills). Simple drills included skills that were minimal in complexity such as simple stickhandling and tight turns, which could be completed easily once the player gained familiarity with the drill and the device. Complex drills included more difficult skills such as open hips, pivots, and quick changes of direction, which required more body and puck awareness and practice to develop the skills.

For PP and PP+OL, the complex skills resulted in significant improvements in overall execution time and competency compared to the simple drills resulting in only improvement in overall execution time (*Figure 5-8*). Due to the nature of the complex drills, improvement in competency of the complex drills is in line with previous statements from Wulf and Shea (2002). They reported that complex drills take more time to learn as there is visually more to “see” and there is an increase in motor requirements to complete the task. The complex skills may have been more sensitive to the learning conditions and resulted in a larger magnitude of learning in both time and competency measures because players may have had less previous exposure and practice of these complex skills. Accordingly, competency of the simple drills may not have improved as participants may have already had a good

understanding of the skills within the simple drills. As stated previously, the simple drills are drills that are easily learned and therefore players were able to improve on the execution time component, however, their competency component was potentially already developed and revealed no significant improvements.

Finally, all skills were executed while skating, so it may also be suggested that skating ability may contribute to SPC development. Two skating assessments, without and with a puck, were conducted to determine if skating execution time improved during the training study. Results from both training groups and the control group revealed no significant differences in any of the skating drills across the three assessment sessions meaning that any improvement in execution time (s) of the SPC skills was not a result of improved skating ability. No differences in skating speed was expected as the training study did not focus on improving skating ability, the intervention focused on teaching and training SPC skills.

The control group findings are consistent with the notion that no training leads to minimal change in execution time (s) and execution competency. Results revealed no significant differences in any outcome measure between  $A_{pre}$  and  $A_{post}$  for the control group. This expected result is consistent with previous findings that physical practice or observation enables one to learn a new motor skill, as the practices provided to the training groups were very specific to the motor skills being trained. When one does not mentally or physically practice a skill or drill, improvement will not occur.

In summary, the training intervention employed for the purpose of the present research was built upon the theories related to learning and specifically,

repetitive physical practice. Training was designed to mimic game-like situations by practicing in small areas, with high traffic, while maintaining control of the body and puck. When combined, the design of the infrastructure (novel training device) packaged with the training program was consistent with the CPF, in which the training stimulus was age/skill appropriate to the participants as the functional task difficulty progressed over time. Physical practice in isolation or in combination with observation elicited a consistent response of improved execution time while maintaining execution competency.

### *Limitations*

Limitations to the current study include, the study participants were 9-11 year old (2005-2006 birth years for the 2016/2017 playing season) male ice hockey players who played the positions of forward and defense. Generalization to other ages or stages of physical or cognitive maturation cannot be assumed without further investigation. The study methodology did not control for the contribution of other hockey training to the study outcomes. All participants continued to participate with their respective teams, including games and practices and were exposed to sport-specific training. Lastly, the PP group indirectly received some observational learning because the drill was explained and demonstrated by the instructor and the players were able to watch the other participants while waiting for their turn. The extent to which players watched other participants complete the drill while they waited their term in line was very individualized.

### *Practical Implications*

The present findings have both theoretical and practical implications. From a theoretical perspective, the results are consistent with previous research detailing the effectiveness of repetitive physical practice in motor skill acquisition. From a practical perspective, the results highlight the importance of physical practice and provide coaches with a training package, which optimizes the use of repetitive physical practice type training. Although observational learning did not reveal significant differences in skill acquisition of time or competency measures, anecdotally observational learning seems to have more of a pedagogical influence in the current study. For example, the organization and flow of the practice seemed to be facilitated by the visual exposure of the athletes to the drills taught in practice. In other words, the athletes appear to be more focused on the task at hand given that they had a visual representation of what they were supposed to be doing. Factors such as limited ice time and the cost of ice time motivate coaches to investigate ways to utilize on-ice practice time efficiently and effectively or in other words, ways to optimize the learning environment and outcomes can be critical for learning. Providing athletes with a visual representation of the drills and overall practice has the potential to benefit the overall flow of practice, as players know what drill is next and less ice time is lost explaining each drill.

Both groups improved in their ability to execute SPC drills. Although significant differences were not consistent across all drills, there is practical significance of increasing speed of execution from 0.5s to 4.2s per isolated drill from  $A_{pre}$ - $A_{post}$ . In hockey, one second can equate to a few feet difference, meaning a breakaway with the puck opposed to skating beside a player racing for the puck.

The team that has possession of the puck has the opportunity to control the speed of a game and attack offensively, whereas the team without the puck can merely defend. Essentially, SPC skills and puck possession can be crucial to the outcome of the game.



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## TABLES

Table 1

*Summary of Cognitivist Learning Theories*

<b>Cognitivist Theory</b>	<b>Year</b>	<b>Stages of Learning</b>	<b>Process</b>	<b>Similar To</b>
<b><i>Fitts and Posner's</i></b> Three Stage Theory	1967	1 – Cognitive	Learning/understanding the skill	
		2 – Associative	Refines movement pattern	
		3 – Autonomous	Developing consistency in performance – learned skill becomes automatic	
<b><i>Adams'</i></b> Closed Loop Theory of Learning	1971	1 – Perceptual Trace	Developing a motor memory through practice	Fitts and Posner's 1 <sup>st</sup> & 2 <sup>nd</sup> Stage
		2 – Memory Trace	Initiation of action	Fitts and Posner's 3 <sup>rd</sup> Stage
<b><i>Gentile's</i></b> Model of Learning	1972	1 – Getting to know the idea	Creating a motor plan	Fitts and Posner's 1 <sup>st</sup> & 2 <sup>nd</sup> Stage
		2 – Fixation/ diversification	Refine and transfer skills	Fitts and Posner's 3 <sup>rd</sup> Stage
<b><i>Schmidt's</i></b> Schema Theory	1975	1 – Recognition Memory	Selection and initiation of a movement based on initial conditions	Adams 1 <sup>st</sup> Stage
		2 – Recall Memory	Sensory actions and the outcome	Adams 2 <sup>nd</sup> Stage

Table 2

*Training Group Protocols*

	Physical Practice Protocol (PP group)	Physical Practice and Observational Learning Protocol (PP+OL group)
Frequency	2x per week	PP: 2x per week OL: 2x per week
Duration	8 on-ice sessions	PP: 8 on-ice sessions OL: 8 off-ice sessions
Type	Stickhandling and puck control	PP: Stickhandling and puck control OL: Videos
Time	50 minutes	PP: 50 minutes OL: 10-15 minutes
Volume	5-8 drills per session	PP: 5-8 drills per session OL: 5-8 corresponding drill videos
Overload	Number and complexity of skills within the drill increased per session	Number and complexity of skills within the drill increased per session

Table 3

*Summarized Player Descriptives for all groups; Means (SD), Frequencies, Ranges*

	PP (n=16)	PP+OL (n= 15)	Control (n=9)	Combined (n=40)
Age (yrs)	9.93±0.59	9.94±0.85	11.0±0.33	10.15±0.77
Height (cm)	144±7	144±4	147±6	145±6
Weight (kg)	41±9	37±8	37±4	39±8
House Experience (yrs)	2±1	3±1	1±1	2±1
Rep Experience (yrs)	2±1	2±1	5±1	3±2
Total Experience (yrs)	4±1	5±1	6±1	5±1
Primary Position				
Forward	9	12	7	28
Defense	7	3	2	12
Handedness				
Right	8	7	2	17
Left	8	8	7	23
Hockey Experience				
House	0 – 5	2 – 4	0 – 3	
Rep	1 – 5	1 – 4	3 – 6	
Total	3 – 7	3 – 7	4 – 7	

Table 4

*Summarized Player Questionnaire Responses*

Measure	Frequency	Percent
Hockey Level		
AAA	9	22.5
AA	3	7.5
A	17	42.5
AE	11	27.5
Individual SPC Practice		
Never	4	10.0
Sometimes	20	50.0
Often	16	40.0
Previous Experience with PEP		
Never	34	85.0
One Session	3	7.5
Multiple Sessions	3	7.5

Table 5

*Coordination Assessment Scores (# of successful repetitions) (Mean  $\pm$  SD)*

Group	Pre		Post		Retention	
	Mean	SD	Mean	SD	Mean	SD
PP ( <i>n</i> =16)	48.69	10.31	52.38	9.60	56.44	10.00
PP+OL ( <i>n</i> =15)	40.07	6.92	53.40	6.98	56.80	6.483
Control ( <i>n</i> =9)	60.22	6.36	65.00	9.42		
Total	48.05	11.19	55.60	9.88	56.61	8.35

*Note.* An increase in number of successful repetitions represents an improvement in coordination.



Table 6

*Execution Time (s) of Forward Skating without Puck (Mean  $\pm$  SD)*

Group	Pre Mean	SD	Post Mean	SD	Retention Mean	SD
PP ( $n=16$ )	7.65	0.50	7.58	0.59	7.60	0.56
PP+OL ( $n=15$ )	7.63	0.51	7.49	0.44	7.61	0.41
Control ( $n=9$ )	6.72	0.24	6.80	0.27		
Total	7.43	0.59	7.37	0.56	7.61	0.48

*Note.* A decrease in time (s) represents faster skating.

Table 7

*Execution Time (s) of Skating with Puck (Mean  $\pm$  SD)*

Group	Pre Mean	SD	Post Mean	SD	Retention Mean	SD
PP ( $n=16$ )	8.26	1.09	8.50	1.22	8.16	1.03
PP+OL ( $n=15$ )	7.96	0.49	8.04	0.58	8.07	0.47
Control ( $n=9$ )	6.99	0.31	7.15	0.36		
Total	7.86	0.90	8.02	0.99	8.12	0.80

*Note.* A decrease in time (s) represents faster skating.

Table 8

*Within Group Paired Samples T-Test for Execution Time of All Drills (t, df and p)*

Group	Drill	<i>T</i>	<i>df</i>	<i>p</i>
Physical Practice (PP)	SIT	3.789	15	.002*
	PT	1.820	15	.089
	MOF	2.980	15	.009*
	PTHF	2.421	15	.029*
	FBT	1.588	15	.133
	COTT	4.221	15	.001*
Physical Practice and Observational Learning (PP+OL)	SIT	4.261	14	.001*
	PT	1.072	14	.302
	MOF	1.964	14	.070
	PTHF	1.572	14	.138
	FBT	1.245	14	.234
	COTT	3.795	14	.002*
Control	SIT	.599	8	.566
	PT	-1.215	8	.259
	MOF	-1.119	8	.296
	PTHF	-.379	8	.715
	FBT	-1.222	8	.256
	COTT	-0.990	8	.351

*Note.* SIT = Stickhandling in Traffic, PT = Power Turn, MOF = McDavid on the Fly, PTHC = Power Turn Half-Crosby, FBT = Forward Backward Transition, COTT = Combined Overall Total Time. \* indicates a significant within-group difference ( $p < .05$ ).

Table 9

*Within Group Paired Samples T-Test for Execution Competency of All Drills (t, df and p)*

Group	Drill	<i>T</i>	<i>df</i>	<i>p</i>
Physical Practice (PP)	SIT	3.159	15	.006*
	PT	-.110	15	.914
	MOF	3.645	15	.002*
	PTHF	.699	15	.495
	FBT	-.850	15	.409
	COTC	1.662	15	.117
Physical Practice and Observational Learning (PP+OL)	SIT	.400	14	.695
	PT	.000	14	1.000
	MOF	1.600	14	.132
	PTHF	-1.661	14	.119
	FBT	-1.169	14	.262
	COTC	-0.245	14	.810
Control	SIT	.667	8	.524
	PT	.756	8	.471
	MOF	1.180	8	.272
	PTHF	.883	8	.403
	FBT	1.315	8	.225
	COTC	2.165	8	.062

*Note.* SIT = Stickhandling in Traffic, PT = Power Turn, MOF = McDavid on the Fly, PTHC = Power Turn Half-Crosby, FBT = Forward Backward Transition, COTC = Combined Overall Total Competency. \* indicates a significant within-group difference ( $p < .05$ ).

Table 10

*Execution Time (s) of SPC Drills (Mean  $\pm$  SD).*

Group	Drill	Pre		Post		Retention	
		Mean	SD	Mean	SD	Mean	SD
Physical	SIT	14.810	3.555	11.557	2.117	12.076	1.888
Practice (PP)	PT	26.187	5.793	24.445	4.253	24.658	3.943
	MOF	16.628	4.243	13.616	3.575	14.862	4.034
	PTHC	30.577	7.683	27.463	4.720	27.535	4.445
	FBT	34.767	8.662	32.640	6.366	33.778	6.062
	COTT	122.969	25.892	109.721	17.940	112.910	17.797
Physical	SIT	16.870	4.421	12.706	3.904	13.419	3.050
Practice and	PT	24.902	3.995	24.392	3.382	24.259	3.234
Observational	MOF	15.829	3.946	13.917	3.410	13.748	3.924
Learning	PTHC	28.160	4.486	26.917	2.760	27.096	3.076
(PP+OL)	FBT	34.309	4.742	32.540	3.974	32.528	4.264
	COTT	119.670	15.427	110.539	13.547	111.249	14.693
Control	SIT	8.700	1.337	8.409	0.628		
	PT	18.661	1.007	19.135	0.816		
	MOF	9.782	2.366	11.227	3.146		
	PTHC	21.898	1.514	22.224	1.828		
	FBT	23.931	1.619	24.918	2.109		
	COTT	83.195	5.131	85.912	6.931		

*Note.* SIT = Stickhandling in Traffic, PT = Power Turn, MOF = McDavid on the Fly, PTHC = Power Turn Half-Crosby, FBT = Forward Backward Transition, COTT = Combined Overall Total Time. A decrease in execution time (s) represents faster completion of SPC drills.

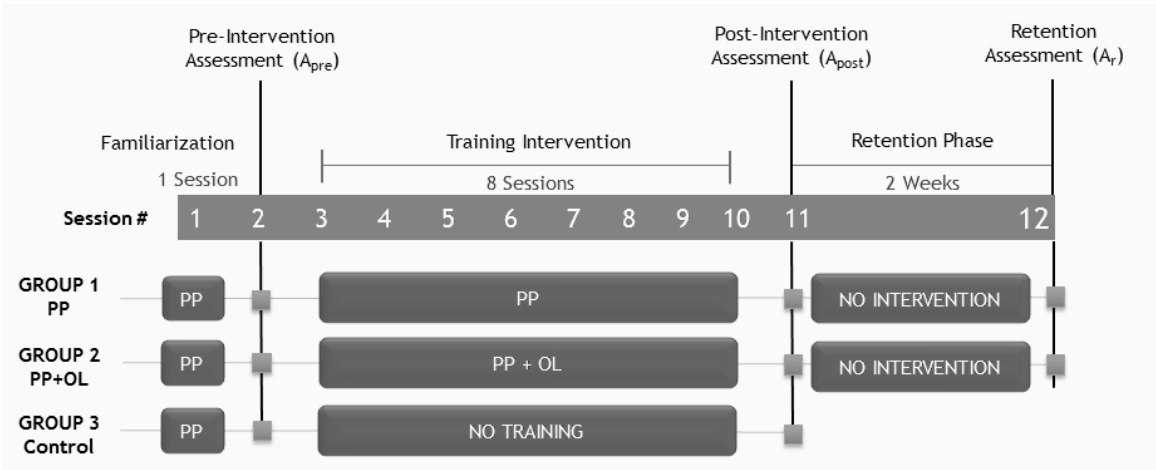
Table 111

*Execution Competency (rating) of SPC Drills (Mean  $\pm$  SD).*

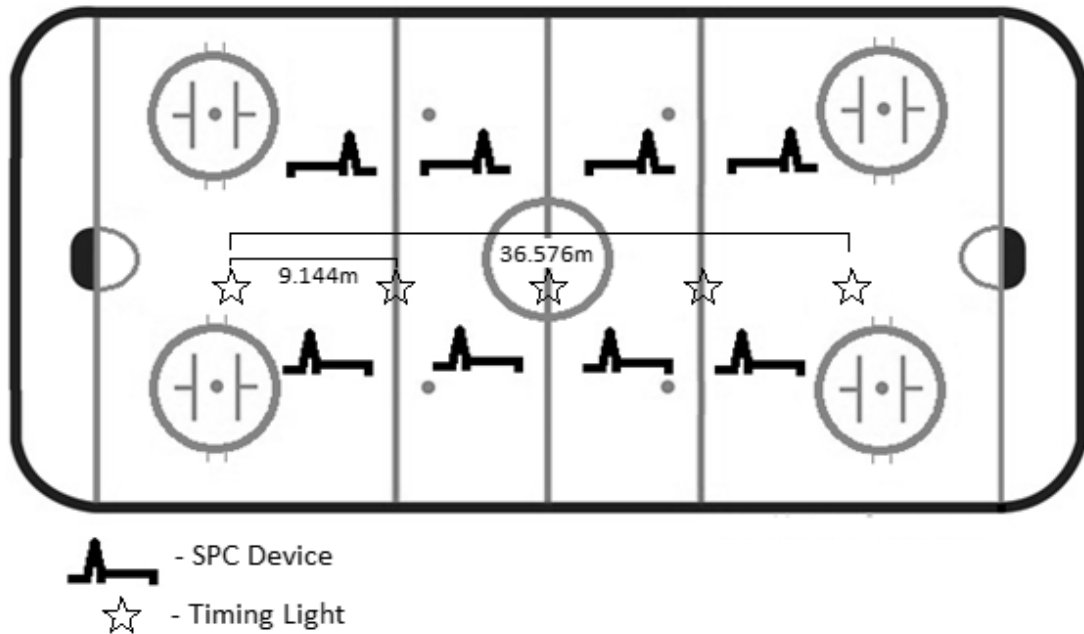
Group	Drill	Pre		Post		Retention	
		Mean	SD	Mean	SD	Mean	SD
Physical	SIT	2.56	1.50	1.25	1.61	3.19	2.46
Practice (PP)	PT	2.25	2.18	2.31	1.82	2.44	2.73
	MOF	4.50	2.50	2.81	1.97	4.31	2.36
	PTHC	4.25	3.40	3.44	3.27	4.94	3.13
	FBT	3.56	2.50	4.19	2.83	4.75	2.24
	COTC	17.38	9.74	14.00	8.41	18.87	9.78
Physical	SIT	2.47	1.51	2.27	2.05	2.20	1.57
Practice and	PT	2.20	1.66	2.20	1.78	2.13	2.89
Observational	MOF	2.80	1.70	1.80	2.01	2.73	2.05
Learning	PTHC	2.80	2.43	3.53	1.25	2.80	1.97
(PP+OL)	FBT	3.27	1.80	4.07	2.12	2.93	2.22
	COTC	13.53	5.90	13.87	5.98	12.73	6.78
Control	SIT	0.89	0.93	0.56	1.13		
	PT	1.11	1.05	0.78	0.67		
	MOF	1.44	1.88	0.56	1.13		
	PTHC	2.33	2.12	1.44	1.88		
	FBT	1.44	1.88	0.56	0.73		
	COTC	7.22	3.31	4.00	3.00		

*Note.* SIT = Stickhandling in Traffic, PT = Power Turn, MOF = McDavid on the Fly, PTHC = Power Turn Half-Crosby, FBT = Forward Backward Transition, COTC = Combined Overall Total Competency. A decrease in competency score (rating) represents fewer errors in execution.

FIGURES



*Figure 1.* Study Timeline. This figure illustrates the groups, type and length of training sessions.



*Figure 2.* Hockey Rink Diagram. This figure illustrates the location of SPC devices and timing lights during training and testing sessions. The timing lights were only on the ice during testing sessions and were placed 9.144m apart with the SPC device directly between two timing lights. The timing lights covered a total distance of 36.576m and recorded total time to complete the drill (s).



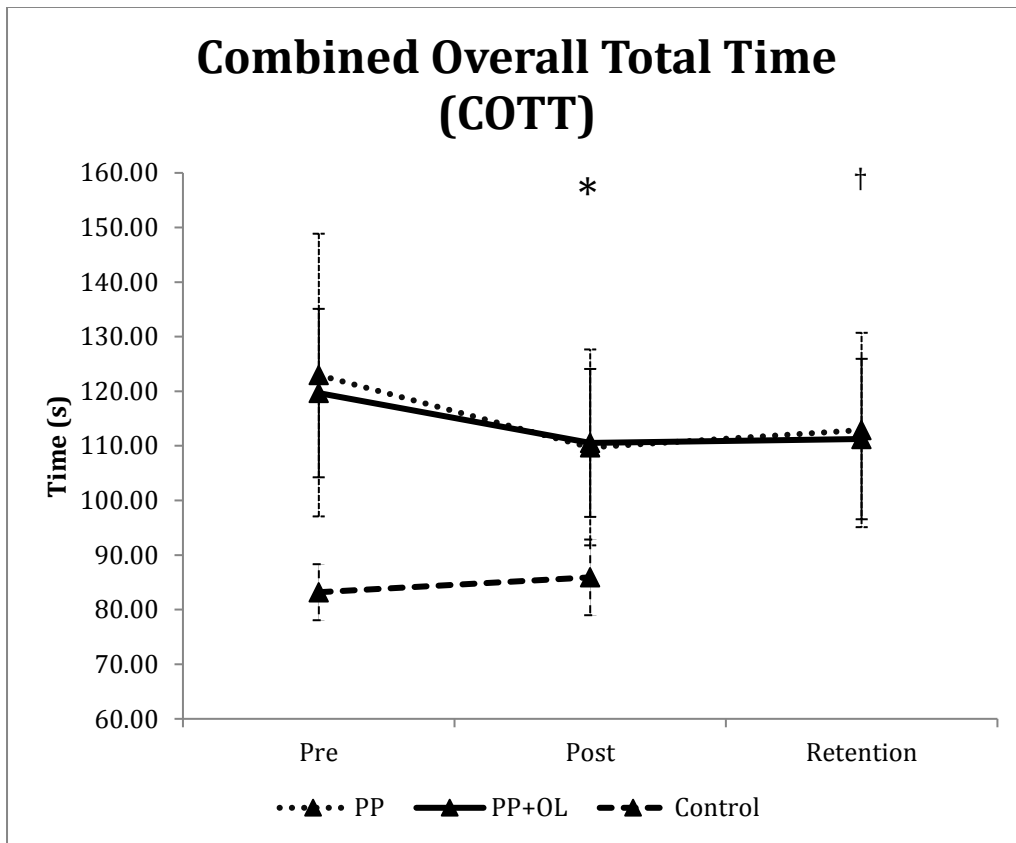
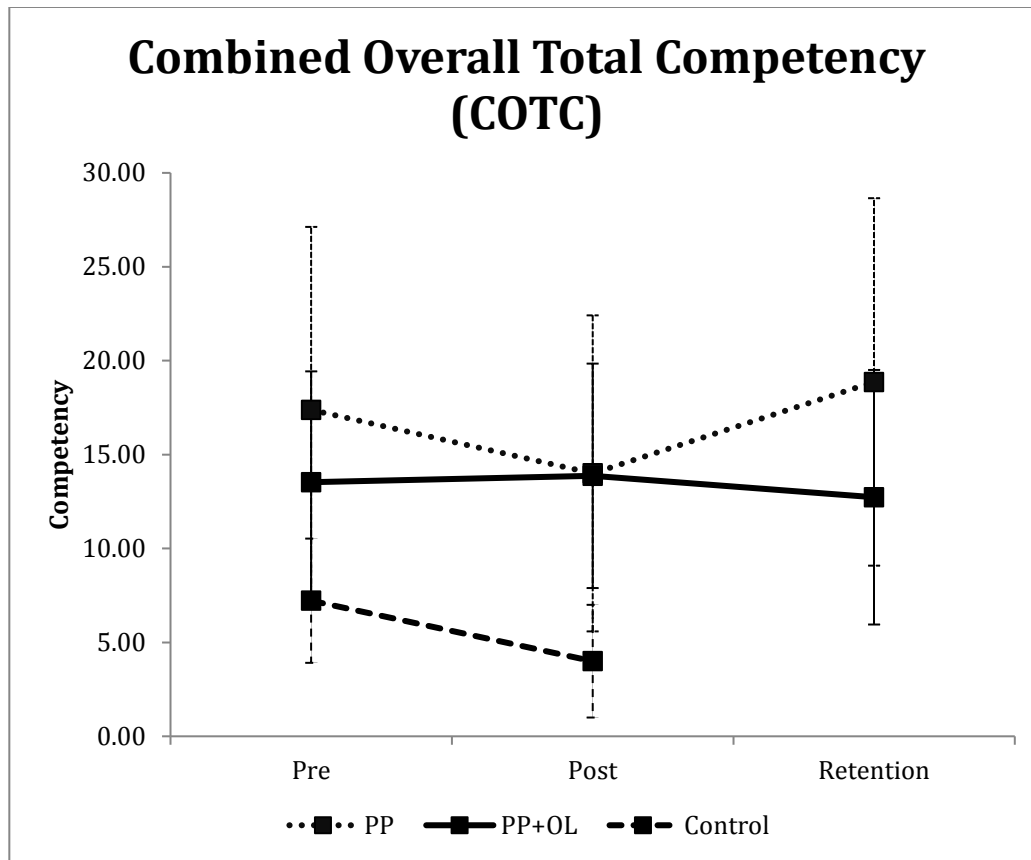
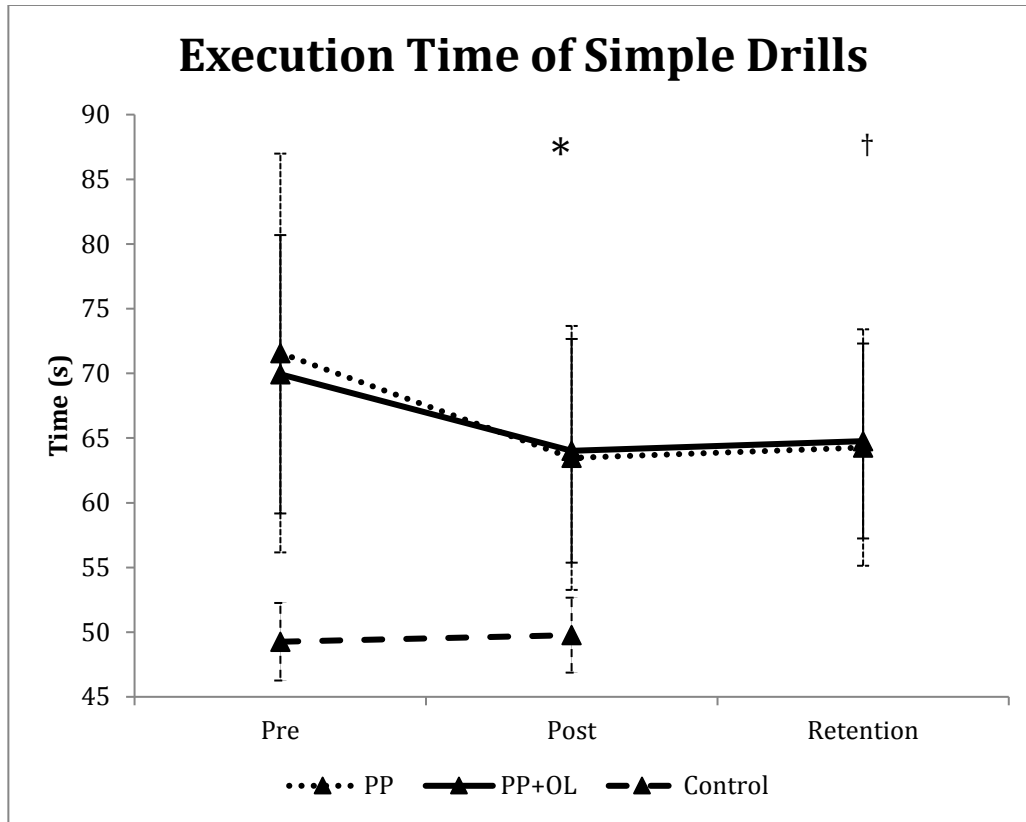


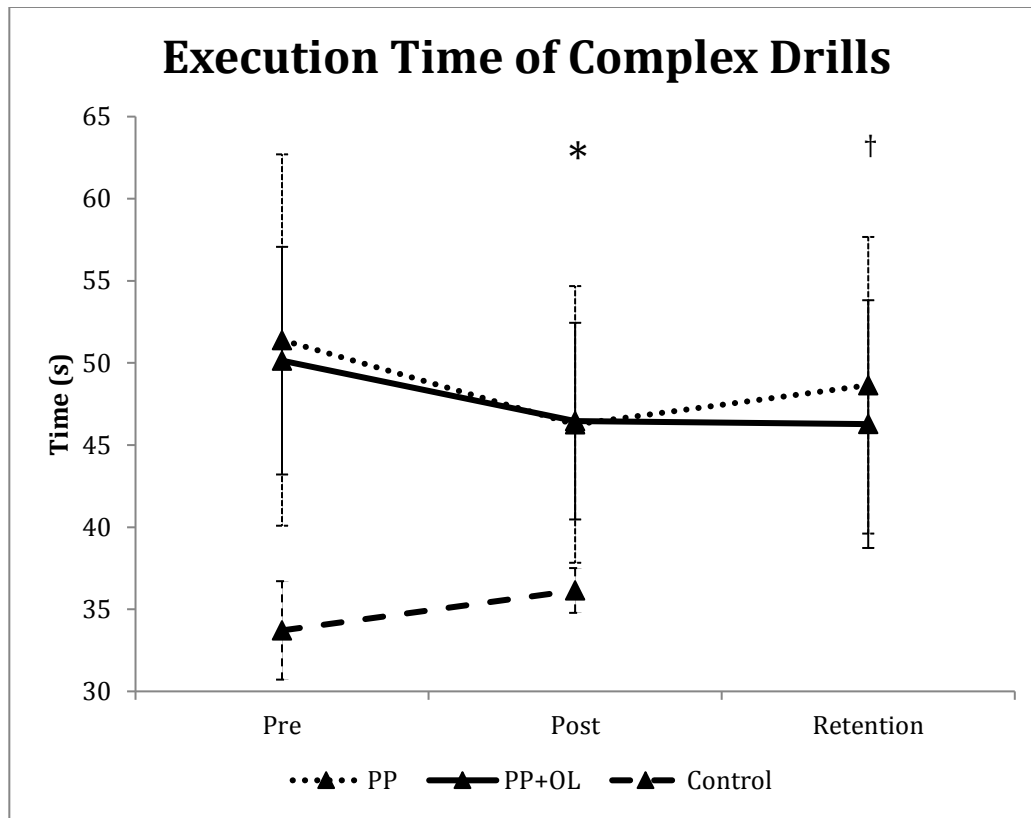
Figure 3. Combined Overall Total Time (COTT) by Group. A decrease in execution time (s) represents faster completion of SPC drills. Vertical lines depict standard deviations of the means. \* Represents a significant main effect of execution time of COTT between  $A_{pre}$ - $A_{post}$  for the training groups ( $p < .05$ ). † Represents a significant main effect of execution time of COTT between  $A_{pre}$ - $A_{ret}$  for the training groups ( $p < .05$ ).



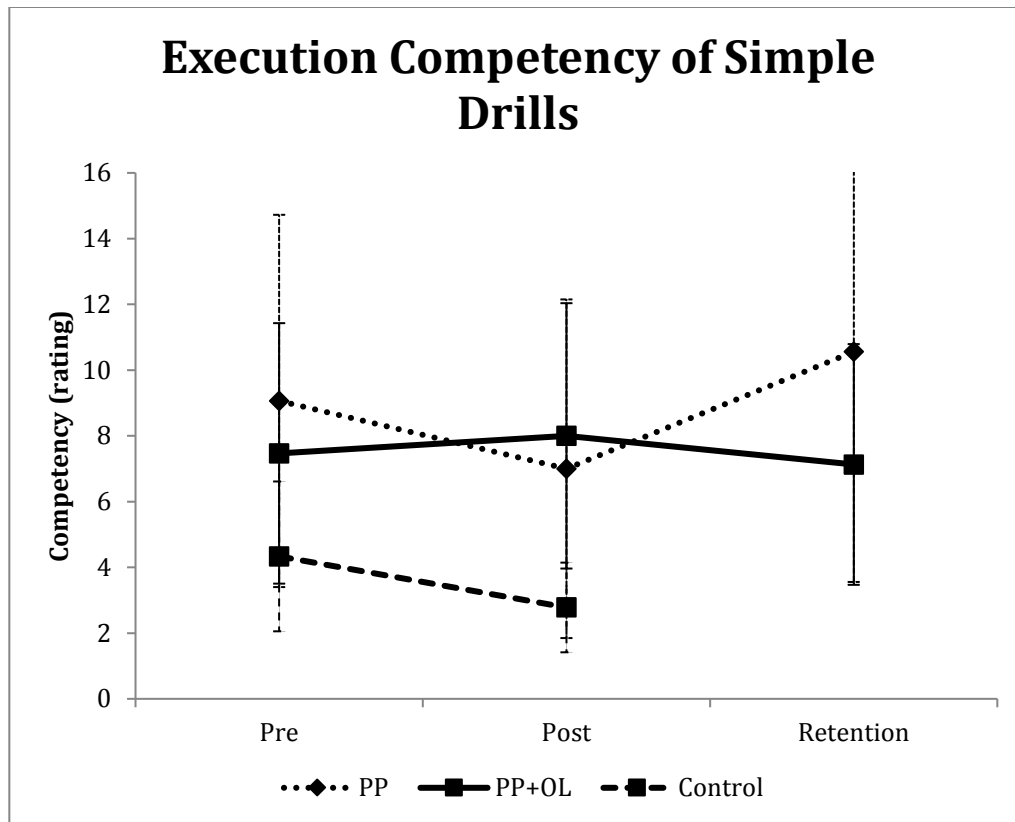
*Figure 4.* Combined Overall Total Competency (COTC) by Group. A decrease in competency score (rating) represents fewer errors in execution. Error bars represent between-subjects standard deviations.



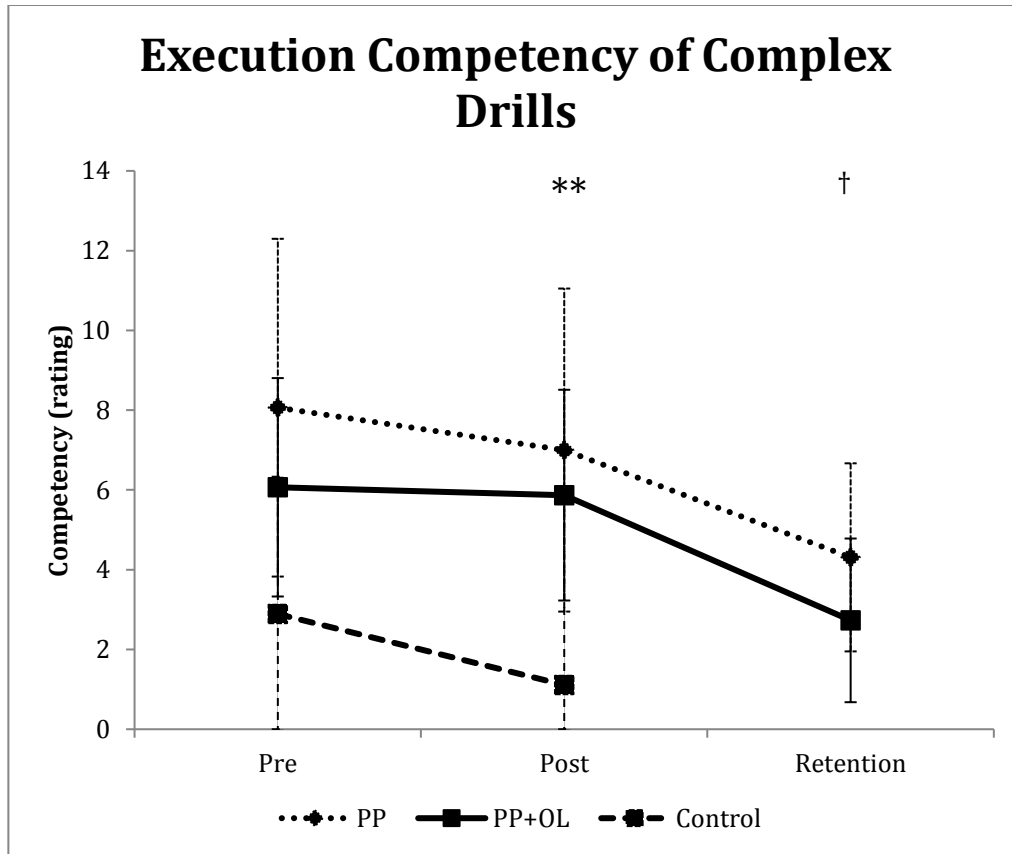
*Figure 5.* Overall Time of Simple Drills by Group. A decrease in execution time (s) represents faster completion of SPC drills. Error bars represent between-subjects standard deviations. \* Represents a significant main effect of execution time of the simple drills between  $A_{pre}$ - $A_{post}$  for the training groups ( $p < .05$ ). † Represents a significant main effect of execution time of the simple drills between  $A_{pre}$ - $A_{ret}$  for the training groups ( $p < .05$ ).



*Figure 6.* Overall Time of Complex Drills by Group. A decrease in execution time (s) represents faster completion of SPC drills. Error bars represent between-subjects standard deviations. \* Represents a significant main effect of execution time of the complex drills between  $A_{pre}$ - $A_{post}$  for the training groups ( $p < .05$ ). † Represents a significant main effect of execution time of the complex drills between  $A_{pre}$ - $A_{ret}$  for the training groups ( $p < .05$ ).



*Figure 7.* Overall Competency of Simple Drills by Group. A decrease in competency score (rating) represents fewer errors in execution. Error bars represent between-subjects standard deviations.



*Figure 8.* Overall Competency of Complex Drills by Group. A decrease in competency score (rating) represents fewer errors in execution. Error bars represent between-subjects standard deviations. † Represents a significant main effect of execution competency of the complex drills between  $A_{pre}$ - $A_{ret}$  for the training groups ( $p < .05$ ). \*\* Represents a significant main effect of execution competency of the complex drills between  $A_{post}$ - $A_{ret}$  for the training groups ( $p < .05$ ).

APPENDIX A – Glossary Terms

*COTC – Combined Overall Total Competency:* The addition of all five SPC drill competency scores to get an overall combined total competency score

*COTT – Combined Overall Total Time:* The addition of all five SPC drill times to get an overall combined total time score

*Device:* The Power Edge Pro apparatus used during training and testing

*Drill:* A task used to train skills through repetition of one or multiple skills at a time

*Execution Competency:* Total competency to complete a drill through four devices

*Execution Time:* Total time to complete a drill through four devices

*Expertise:* Possessing exceptional skill in a certain field

*Infrastructure:* The developed system/device used to teach, learn and train stickhandling and puck control skills

*Interval Time:* The time to complete one device within an assessment drill

*PEP – Power Edge Pro:* The Company that created and marketed the training devices and instructional app used in this study

*PP – Physical Practice:* Condition where participants only complete the training through multiple on-ice repetitions

*PP+OL – Physical Practice and Observational Learning:* Condition where participants receive observational learning in the form of a video with an expert model and on-ice practice in addition to the on-ice physical practice

*RFID – Radio Frequency Identification System:* Tag used for identifying and tracking participant scores within a data collection application

*Skill:* A component of a drill

*SPC – Stickhandling and Puck Control:* Maintaining puck possession through the use of the players stick

*Tactical Touches:* Player executes puck through the device and regains immediate possession



APPENDIX B– Letter of Invitation

The Effectiveness of Infrastructure and Expertise on the Acquisition of Stickhandling and Puck Control Skills Using a Novel Device in Competitive Hockey Players

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**INVITATION**

You are invited to participate in a Master's thesis research project examining the effectiveness of physical practice (PP) versus physical practice and observational learning (PP+OL) using a novel training device on skill acquisition and retention of stickhandling and puck control (SPC) skills in competitive hockey players.

**WHAT'S INVOLVED**

As a participant, you will be asked to complete EIGHT, 50-minute training sessions scheduled TWICE a week for FOUR weeks, and THREE assessment sessions scheduled pre, post and 2 weeks post training to assess retention. In addition, participants will receive adequate familiarization of assessment and training skills prior to the pre assessment session. All sessions will be scheduled during the season; therefore we will consult with your coach to ensure that the research schedule will not conflict with your practice and game schedule. Only players who are injury free are eligible to participate. Details of the training and assessment sessions are as follows:

**Training:** All training sessions will be instructed by the student researcher and scheduled at the teams' home arena: (For example: Welland Youth & Main Arenas, 501 King St. W, Welland, ON.) Teams will be randomly assigned to one of two training groups: physical practice (PP) or physical practice and observational learning (PP+OL). Training sessions will take approximately 50 minutes and consists of a five-minute warm-up, 40 minutes of SPC practice, and five minutes of mini team or mini game SPC practice.

**1. Physical Practice Group (PP)**

The PP methodology is based on a teach/learn process with verbal instructions and a live demonstration for each drill. This group will complete the 8 training sessions using only the novel training device and methodology described above.

## 2. Physical Practice and Observational Learning Group (PP+OL)

The PP+OL methodology is based on a teach/learn process as described in PP in combination with video observations prior to the on-ice session. In addition, this training group will receive observational learning in the form of instructional videos before and after each training session. To facilitate this, a video screen is set up at the arena each session. Participants are required to watch each drill for the session one time; totaling 7-8 drills before each session. Participants are encouraged to ask questions at the end of each drill video. Each drill video is approximately 60-90 seconds. To prepare the participant for the next training session, participants will watch the three new drills for the next session immediately after training. The observational component will take approximately 10-15 minutes prior to the ice session and approximately 5-8 minutes immediately after the ice session.

### *Pre and Post Training Assessments*

1. The off-ice assessment will be scheduled at the teams home arena. It will take approximately 30 minutes to complete and consists of two anthropometric measurements: height (cm) and weight (kg), and a modified Aggiss and Walsh (1986) coordination assessment.

- Coordination assessment consists of a modified Aggiss and Walsh (1986) field hockey coordination assessment that consists of moving a ball with a stick from left to right across a measured distance of 0.61 m (2 feet) in 30 seconds. The total number of successful repetitions from left to right in 30 seconds will be recorded. Participants will complete two trials and their best trial will be recorded and used in the analysis.

2. The on-ice assessment will also be schedule at the team's home arena. It will take approximately 50 minutes to complete and consists of 2 skating drills and 5 selected SPC drills<sup>2</sup> that represent SPC skills commonly used in a game (Appendix D). The order of the drills will remain consistent in each assessment session throughout the study. A two-minute rest period between drills will be given to participants to ensure adequate rest among participants. The first skating drill will be repeated twice with their best trial being recorded. All drills will be performed with sticks and a puck; however, the first drill is completed without a puck. A Swift™ timing light system will measure gate interval time (4 gates, G1, G2, G3, G4; s) to assess individual SPC skill execution time and total time to complete the drill to measure overall execution time (TT; s). Participants will be fitted with a small wireless device known as a Radio Frequency Identification (RFID) tag to individually identify each participant within the software recording system. If a player fails to complete the drill completely (e.g., falls, knocks over device, etc.), no score will be allocated and the player will be asked to repeat the drill. Execution competency of the four SPC drills only will be assessed using an expert and rating scale. The same expert will be used throughout the study to ensure consistency. Skills will be rated based upon a four-criteria checklist: 1. mishandle of the puck, 2. loss of puck, 3. body hits device, and 4. puck hits device. The expert will assign a score of 0-3 for each of the four criterion based on

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<sup>2</sup> The industry partner has identified the SPC drills for the purpose of this assessment.

the participants performance. A score of 0 represents no mistake in that criterion. A score of 3 represents 3 or more mistakes in a criterion. An overall score out of 12 will be recorded for each SPC drill with 0 representing superior execution competency to 12 representing no execution competency. Encouragement from the instructor will be given throughout all assessments to promote maximal effort. The same arena will be used for all assessment sessions with the devices placed in the same set-up. Participants will wear full equipment and have skates sharpened for game-like conditions based on personal preference.

### **POTENTIAL BENEFITS AND RISKS**

Potential benefits of participation include the opportunity to complete an eight-session SPC training program using a novel training device that has the potential to increase speed and execution competency of SPC skills. This study also has the potential to benefit the scientific and athletic community by adding to the pool of knowledge with regard to effective training practices of complex motor skills and more specifically, determine if the combination of infrastructure and expertise can enhance traditional motor training.

During training and assessments, participants may experience risk factors associated with playing the game of hockey, such as incidental contact with other players, the ice surface or surrounding boards, tripping/falling, getting hit with a puck, etc. The training device may pose as a potential tripping hazard to players as some drills instruct players to maneuver around and over the device.

In case of emergency, emergency procedures will be enacted in accordance to the teams' home arena (i.e. Welland Arena) emergency action plan.

Although players will be recruited based on team involvement, participation in the study will be voluntary on an individual basis and each player may choose to accept or refuse participation. Players who do not wish to participate will suffer no penalty. Coaches will not be privy to any individual or player results.

### **CONFIDENTIALITY**

All information you provide is considered confidential. To avoid exposure of personal data and ensure confidentiality of data collection, participants will be fitted with a Radio Frequency Identification (RFID) tag for all on-ice assessments. Data from off-ice assessments and questionnaires will be cross-referenced with RFID identifiers by the researcher so that names will not appear on the data forms. All data is confidential and only the principal and student investigator will have access. Following publication, electronic copies of data will be distorted to remove participant names and retained for a period of five years. The data will be stored on a research dedicated portable hard drive that is password protected by the principal researcher.

Access to this data will be restricted to Dr. Kelly Lockwood and Jessica Fickel.

### **VOLUNTARY PARTICIPATION**

Participation in this study is voluntary and is not a mandatory team activity. Should the participant wish to withdraw from this study, they may do so by verbally informing the principal investigator or student investigator, without any penalty. If the participant chooses to withdraw, their data will be destroyed by deleting any file and shredding any information related to their participation at the end of the training or assessment sessions. Their data will not be shared or used for further analysis.

### **PUBLICATION OF RESULTS**

A summary of the results of this study will be available and distributed to all participants approximately one month after the final assessment session is completed. This will include a personalized summary with both individual results and a comparison to average group scores. Furthermore, scientific results of this study may be published in academic or practitioners journals and/or presented at scientific conferences to advance our knowledge of the effectiveness of physical practice and observational learning on the acquisition of SPC skills in competitive ice hockey players. Only age group and playing positions of the participants will be utilized as possible identifiers in the analysis and publication of results.

### **CONTACT INFORMATION AND ETHICS CLEARANCE**

If you have any questions about this study or require further information, please contact Dr. Kelly Lockwood or Jessica Fickel using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University [File# 15-198]. If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, [reb@brocku.ca](mailto:reb@brocku.ca).

If you are interested in participating please complete the attached Informed Consent and submit it to Dr. Kelly Lockwood or Jessica Fickel using the contact information provided above. Please keep a copy of this form for your records. Thank you for your assistance in this project.

Jessica Fickel and Dr. Kelly Lockwood

## APPENDIX C – Informed Consent

### CONSENT FORM

I agree to participate in this study described above. I have made this decision based on the information I have read in the Information-Consent Letter and assent that:

- I have had the opportunity to receive any additional details I wanted about the study and
- I understand that I may ask questions anytime with regard to the study.
- I understand that I may withdraw this consent at any time.
- I understand that this is not a team-required activity and I am not obligated as a team member to participate in the study.
- I understand that training and assessments will take place in groups with other participants viewing my performance, however, only the researchers will see my scores

For Participants and Guardians to complete:

Participant Assent:

In signing this form, I \_\_\_\_\_ (Participant's Name) and \_\_\_\_\_ (Guardian's Name) acknowledge that I have received an explanation about the nature of the study and its purpose.

Parental/Guardian Consent:

I \_\_\_\_\_ (Guardian's Name) give my permission for \_\_\_\_\_ (Participant's Name) to participate in the research as described above conducted by Dr. Kelly Lockwood and Jessica Fickel. I have made this decision based on the information I have read in the Information-Consent Letter.

Photo Permission:

In signing this form, I \_\_\_\_\_ (Participant's Name) and \_\_\_\_\_ (Guardian's Name) give permission to for photos and videos of \_\_\_\_\_ (Participant's Name) to be used by Dr. Kelly

Lockwood and Jessica Fickel in presentations of the research (E.g. poster presentation at a conference).

(NOTE: Photo permission is NOT required to participate.)

Participants Name: \_\_\_\_\_

Participants Signature: \_\_\_\_\_

Guardian's Name: \_\_\_\_\_

Guardian's Signature (if under 18): \_\_\_\_\_

Date: \_\_\_\_\_

## APPENDIX D– Hockey Experience Questionnaire

**PARTICIPANT INFORMATION*****To be completed by participant:***

Name: \_\_\_\_\_

Date of Birth (mm/dd/yy): \_\_\_\_\_ Age at start of program: \_\_\_\_\_

Team: \_\_\_\_\_

Level (circle one):     A     AA     AAA

Primary Position Played (circle one):             Forward             Defense

Shoots (circle one):             Right             Left

Years of Hockey Experience: Rep: \_\_\_\_\_ House league: \_\_\_\_\_ Total: \_\_\_\_\_

Do you practice stickhandling outside of your regular practices? (circle one):

Never             Sometimes             Often

Have you ever used a commercially developed stickhandling program before? (circle one):

Yes     No

If yes, when, what product/company and for roughly how long? \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_***To be completed by evaluator:***

Height: \_\_\_\_\_

Weight: \_\_\_\_\_

## APPENDIX E – Assessments

***Off-ice Assessments***

## 1. Upper-Body Coordination

Player stands with feet shoulder width apart. Player had 30 seconds to move the puck from left to right as many times as possible across a measured out distance of 0.61m (2 feet) that was marked on the stickhandling surface. Each time the player successfully controls the puck over an end line, a score of 1 will be added; left to right back to left equals 2 and so on. If the ball does not fully cross the line, no score is added. The total number of successful repetitions (line crosses) in 30 seconds will be recorded.

***On-ice Assessment Drills***

For all on-ice drills, participants were fitted with a small wireless device known as a Radio Frequency Identification (RFID) tag to individually identify each participant within the software recording system. Participants completed a 5-10 minute free warm-up where players could skate around the ice and stickhandle as desired. For each drill, a timing light signaled participants to begin and verbal encouragement was given to encourage maximal effort. All drills were completed in the same order for each assessment throughout the study. Participants completed the first skating assessment twice with recording both scores.

***Skating Assessments***

## 1. Skating Assessment 1 (repeated twice) – Forward Skating without Puck (FS)



Player stands at start line. Player skates as fast as they can to the finish line.

2. Skating Assessment 2 – Forward Skating with Puck (FSP)

Player stands at start line with puck behind line. Player skates as fast as they can to the finish line while pushing the puck with their stick.

***Stickhandling and Puck Control (SPC) Assessments***

The five SPC assessments will be conducted using the same novel SPC device used in training. Testing of SPC skills will be composed of stickhandling through, around and over the device while maintaining control of the puck and controlling the body in motion. For all assessments, players start the assessment with puck and body behind the start line. Movement is initiated when the light goes off. All drills are completed with participants starting the drill on their forehand side and alternating each device.

3. SPC Assessment 1 – Stickhandling in Traffic (SIT)

Player shuffle as fast as possible with feet on either side of each device putting the puck under each device once.

4. SPC Assessment 2 – Power-turn (PT)

Player skates to device places the puck under the device and does a power turn (tight turn) to retrieve the puck on the opposite side of the device, they are now facing the end of the rink they just came from. Player continues around the back of the device towards the second device and repeats.

5. SPC Assessment 3 – McDavid on the Fly (MOF)

Player skates up to the device, places the puck under the device to the opposite side and opens their hips to the side they placed the puck to without going over or around the device.

6. SPC Assessment 4 – Power-turn Half-Crosby (PTHC)

Similar to PT, player skates to device places the puck under the device and does a power turn (tight turn) to retrieve the puck on the opposite side of the device, they are now facing the end of the rink they just came from. Player places the puck under the stick of the device to opposite side and opens their hips to propel the player around the back of the device and retrieve the puck continuing up the ice to the next device.

7. SPC Assessment 5 – Forward-Backward Transition (FBT)

Player skates to the top of the first device and pivots backwards while maintaining control of the puck. Player skates alongside the device when they place the puck through the stick of the device, player retrieves the puck immediately stopping beside the device with puck behind the stick of the device. Player puts the puck back through the stick of the device regaining control of the puck racing to the next device.

## APPENDIX F - Criteria Checklist for SPC Drills

Participant Number: \_\_\_\_\_

SPC Assessment: \_\_\_\_\_

## Device 1:

- |                        |                            |                            |                            |                             |
|------------------------|----------------------------|----------------------------|----------------------------|-----------------------------|
| a. Mishandle the puck? | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| b. Loss of puck?       | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| c. Body hits device?   | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| d. Puck hits device    | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |

## Device 2:

- |                        |                            |                            |                            |                             |
|------------------------|----------------------------|----------------------------|----------------------------|-----------------------------|
| a. Mishandle the puck? | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| b. Loss of puck?       | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| c. Body hits device?   | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| d. Puck hits device    | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |

## Device 3:

- |                        |                            |                            |                            |                             |
|------------------------|----------------------------|----------------------------|----------------------------|-----------------------------|
| a. Mishandle the puck? | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| b. Loss of puck?       | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| c. Body hits device?   | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| d. Puck hits device    | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |

## Device 4:

- |                        |                            |                            |                            |                             |
|------------------------|----------------------------|----------------------------|----------------------------|-----------------------------|
| a. Mishandle the puck? | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| b. Loss of puck?       | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| c. Body hits device?   | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |
| d. Puck hits device    | 0 <input type="checkbox"/> | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3+ <input type="checkbox"/> |

## APPENDIX G – On-ice Training Drills

## PRACTICE OUTLINE

Session	Drill	Tactical Touches	Reps	Sets	Volume
1	Stickhandling in Traffic	1	8	3	24
	Power Turn	1	8	3	24
	Crossover w/o puck	0	8	1	0
	Crossover with puck	1	8	2	16
	Transition Forwards to Backwards	2	8	3	48
	Transition Forwards to Backwards Sticks	2	8	3	48
	<b>TOTAL</b>		<b>48</b>	<b>15</b>	<b>160</b>
2	Stickhandling in Traffic	1	8	2	16
	Crossover with puck	1	8	2	16
	McDavid on the Fly	1	8	2	16
	McDavid Pull Push (around device)	0	8	1	0
	Power Turn Half Crosby	2	8	3	48
	Forward Transition to Backwards with Sticks	2	8	3	48
	Freestyle	3	6	3	54
	<b>TOTAL</b>		<b>54</b>	<b>14</b>	<b>166</b>
3	Stickhandling in Traffic	1	8	1	8
	Crossover with puck	1	8	1	8
	McDavid on the fly	1	8	1	8
	Power Turn	1	8	1	8
	McDavid Pull Push (around device)	0	8	1	0
	Power Turn & Power Move	2	8	3	48
	Up and Down Quick Hands	1	8	3	24
	Crosby on the Fly Down Low	3	8	3	72
	<b>TOTAL</b>		<b>64</b>	<b>14</b>	<b>176</b>
4	Stickhandling in Traffic	1	8	1	8
	McDavid on the Fly	1	8	1	8
	McDavid Pull Push	1	8	2	16
	Up and Down Quick Hands	1	8	1	8
	Up and Down Quick Hands Both Knees	1	8	3	24
	Power Turn & Puck Under Crossover	2	8	3	48
	Forwards Transition Backwards	2	8	3	48
	McDavid Slingshot	2	6	3	36
	<b>TOTAL</b>		<b>62</b>	<b>17</b>	<b>196</b>

## EFFECTIVENESS OF INFRASTRUCTURE AND EXPERTISE 100

Session	Drill	Tactical Touches	Reps	Sets	Load
5	Stickhandling in Traffic	1	8	1	8
	McDavid on the Fly	1	8	1	8
	McDavid Pull Push	1	8	1	8
	Powerturn Half Move & Power Move	3	8	1	24
	Duncan Keith Escape (No crossover)	1	6	3	18
	Change of Direction	3	6	3	54
	Transition Forwards to Backwards with Passing	2	6	3	36
	Free Style	3	6	3	54
	<b>TOTAL</b>		<b>56</b>	<b>16</b>	<b>210</b>
6	Stickhandling in Traffic	1	8	1	8
	McDavid on the Fly	1	8	1	8
	McDavid Pull Push	1	8	1	8
	Powerturn Half Move & Power Move	3	8	1	24
	Transition Forwards to Back Outside Pull East-West	3	8	3	72
	Duncan Keith Escape (With crossover)	2	6	3	36
	Change of Direction - Cut through Small PEP	3	6	3	54
	Three Shot Swing	1	3	4	12
	<b>TOTAL</b>		<b>55</b>	<b>17</b>	<b>222</b>
7	Stickhandling in Traffic	1	8	1	8
	McDavid on the Fly	1	8	1	8
	McDavid Pull Push	1	8	1	8
	Powerturn Half Move & Power Move	2	8	1	16
	Duncan Keith Escape	1	6	1	6
	McDavid Freestyle (20 sec on, 20 sec off)	12	1	6	72
	Change of Direction McDavid Triple	5	6	3	90
	Give and Go Shot	4	1	4	16
	<b>TOTAL</b>		<b>46</b>	<b>18</b>	<b>224</b>
8	Stickhandling in Traffic	1	8	2	16
	PowerTurn	1	8	2	16
	McDavid on the Fly	1	8	2	16
	PowerTurn Half Crosby	2	8	2	32
	Forward/Backward Transition	2	8	2	32
	Duncan Keith Escape Freestyle	2	6	3	36
	Freestyle	4	6	3	72
	<b>TOTAL</b>		<b>52</b>	<b>16</b>	<b>220</b>

APPENDIX H - DNF Criteria

**Fail**

1. Fall
2. Crossing a laser pre-maturely
  - a. Crossing a laser without the puck
  - b. Crossing the laser before completing the full maneuver around the device
3. Puck leaves testing area (width of lasers to boards)
4. Dislodges device and maneuver is no longer possible to finish
5. Completing the wrong maneuver
6. Not alternating side to side

**Acceptable**

1. Puck hits device and stays within testing area
  - a. Player receives a score of 1 for each time the puck hits the device
2. Player's body hits the device but device stays in place and player is able to continue manoeuvre
  - a. Player receives a score of 1 for each time their body touches the device (including stick and skates)
3. Player mishandles or fumbles the puck within the stick's range of motion while staying on the desired path of the drill
  - a. Player receives a score of 1 for each time they mishandle or fumble the puck
4. Player loses the puck and has to go off the desired path to retrieve the puck and continue the manoeuvre
  - a. Player received a score of 1 for each time they lose the puck

Before testing: Participants are able to have one practice attempt at each drill (not in the testing area).